JOURNAL

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Contents

PAGE	
675	A CHAPTER BEGINS
676	WATTMETERS *by* H. D. HAWKES and A. H. M. ARNOLD, Ph.D., D.Eng.
684	SIMULATORS *by* J. J. GAIT, M.A., B.Sc., and LT.-CMDR. F. R. J. SPEARMAN, R.N.(Ret.)
687	THE INCORPORATED BENEVOLENT FUND
688	THE TRANSATLANTIC TELEPHONE CABLE PROJECT
690	TELECOMMUNICATION IN THE COLONIES
691	VALVE LIFE *by* G. H. METSON, M.C., Ph.D., M.Sc.
693	SUPPLY SECTION SUMMER VISIT TO HOLLAND
695	DIGESTS OF PAPERS IN THE *PROCEEDINGS*
704	HOME EVENTS
706	NEWS FROM ABROAD
708	PROBLEMS CONCERNING THE DISTRIBUTION OF ELECTRICITY IN AUSTRALIA *by* E. SANDS
710	CORRESPONDENCE
711	OBITUARY
715	MONOGRAPHS AND PAPERS PUBLISHED SEPARATELY THIS MONTH
717	SOME RECENT BOOKS
720	ANNOUNCEMENTS TO MEMBERS
722	LIBRARY ACCESSIONS
723	FORTHCOMING EVENTS AT SAVOY PLACE
724	BRITISH NUCLEAR ENERGY CONFERENCE
724	ELECTIONS AND TRANSFERS
726	CONTENTS OF THE CURRENT ISSUES OF THE *PROCEEDINGS*

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A CHAPTER BEGINS

OVER TWELVE YEARS AGO THE COUNCIL OF THE Institution appointed a committee to make a special study of the education and training of electrical engineers. The field was a broad one and after a general review of the whole, and of the relationship of the various parts, the Committee examined each part in detail. The Council have received over the years a number of reports which have resulted from the studies of the Committee and they have ordered most of these to be published. In recognition of the importance of this work, the Committee, with some changes in personnel, was established as the permanent Education and Training Committee of the Council, a development which has left the Examinations Committee free to devote all their attention to the other branch of the Council's educational work.

The development outside the universities of technological, as opposed to technical, education, has during these years received much attention from the Education and Training Committee and the Council themselves, who have maintained close contact with the Councils of the other two major engineering Institutions. Besides their own lengthy deliberations members of the Committee have spent many hours in discussions with the Percy Committee and with the National Advisory Council for Education in Industry and Commerce, as well as with successive Ministers of Education and their officers. The differences between the three Councils' proposals for development and those of the National Advisory Council were made clear in a statement which the Councils presented to the Minister in 1953. Thereafter, further efforts were made to resolve the differences between the Institutions and the National Advisory Council, but unfortunately the discussions eventually broke down.

The recommendations which the National Advisory Council presented to the Minister last year meet some of the Institutions' points but others were unresolved; these were outlined in the last Annual Report of the Council of The Institution.

Since then, in July, the umpire has given his decision and the years of discussion have ended. The country's need of a firm plan is so urgent that more harm would be done by discussing the shortcomings of the one adopted than by exerting every effort to make it work.

A new autonomous body, a Council with two Boards of Studies, is now being set up, and this will, by the recognitions and awards it gives, largely control the development of technological education outside the universities. In their decision to do their utmost to obtain the best results from the new plan, the Council have been encouraged by the acceptance of an eminent engineer and industrialist of the Chairmanship of the new Council. Lord Hives, in a meeting with the three Presidents, at which the Minister of Education was present, gave an outline of the objectives that he intended to place before the new Council, and if these are accepted in principle many of the uncertainties about the effectiveness of the plan will disappear.

In nominating a Vice-President and a Member of Council for appointment as members of the Board of Studies in Engineering, to represent The Institution, the Council hope to be supported by all members of The Institution who are interested in this important subject, and that for their part members will assist in the development of the scheme.

A long chapter ends and a new one begins. An appropriate ending to the old was a debate in the House of Commons on July 21st, and a fitting opening to that part of the new chapter which deals with the parallel developments in universities will be found in the Inaugural Address of the Rector of Imperial College, delivered on the 11th October, 1955.

Journal I.E.E., November 1955

An Electrical Engineering Review

WATTMETERS

This article is one of a series of reviews, for the non-specialist, of limited aspects of electrical engineering, and gives a broad survey of the design and use of modern power-measuring instruments. Mr. Hawkes is with Elliott Brothers, and Dr. Arnold is at the National Physical Laboratory.

H. D. HAWKES, *Member*
A. H. M. ARNOLD, Ph.D., D.Eng., *Associate Member*

Introduction

IT is the purpose of this review to present to the electrical engineer a picture of current practice in the art of design, performance and application of commercial power-measuring instruments. By far the largest demand for power measurement is in the field of power engineering at mains-supply frequencies. The design of the modern wattmeter for this purpose has nearly reached finality; the desirable performance has been attained and it is unlikely that a higher performance will be required in the near future. In fact, many instruments in production to-day have undergone only design-detail change in the last twenty years. There will, of course, always be design-detail modifications for any special application and with the introduction of new materials, methods of production and methods of presentation.

The main advance in recent years has been due to the growth of measurements in the frequency range up to 2 500 c/s and a considerable effort has been made to improve the frequency response of instruments for this purpose. Above this frequency, until the microwave range is reached, there has been little demand for application of power-measuring instruments. It would be a major task to discuss in detail the design and performance of all past and present types of wattmeter and it is therefore considered advisable to limit the scope of this review to present commercial instruments. Actually, the number of basic types is not large, but each manufacturer has, in design detail, different arrangements of these types and only a limited number of examples can be presented in this article.

Types of Wattmeter

There are four types of wattmeter used in the audio-frequency range of measurement—induction, dynamometer, thermal and electrostatic. The type which has the most general application is the dynamometer and it is with this instrument that the article is mainly concerned. Microwave wattmeters are of more recent application but mention is made of a commercial instrument for these high frequencies.

General Technical Considerations

When selecting the type of instrument for a particular purpose consideration has to be given to many factors of varying importance, according to the application. Size and cost have become increasingly important, particularly in the field of industrial and service measurements, whereas they may have little bearing on the selection of instruments for use in the standards room.

Portability, visibility at a distance, robustness and reliability of the instrument require due consideration, but the factors which are of main interest to the electrical engineer are undoubtedly accuracy, readability and sensitivity.

Accuracy is the degree of perfection to which the instrument will comply under specified conditions and this is usually expressed as the percentage error of indication, or percentage error of full scale deflection. A British Standard (B.S. 89: 1954) gives only two classifications—"precision" and "industrial"—the former being "for use where high accuracy is required" and the latter "for use where high accuracy is not required." The permissible error in the "precision" class is sensibly half that of the "industrial" class. (The accuracy classification used in some Continental countries is very much wider and is not covered by a national specification, and the manufacturers mark their instruments in percentage full scale deflection according to their accuracy claims, e.g. Class 0·1, Class 0·2, Class 0·5, etc.) On null-point indicators the accuracy is normally quoted as a percentage error of the restoring measurement at the nominal voltage and current of the measuring instrument. The accuracy of a commercial wattmeter is largely limited by its cost; improvement in performance can usually be obtained by special adjustments of the instrument but this work can so increase the cost that it becomes prohibitive.

Readability is the minimum change of deflection which is readable and this is often increased by the use of optical magnification, particularly on precision instruments. The instrument accuracy cannot be better than its readability and is usually less on account of errors, one of which is termed *instability*. Instability may be considered as the error of the instrument arising from factors which are not fully known or fully under control.

The instrument sensitivity may be defined in two ways, one with respect to the power measured by the instrument and the other with respect to its apparent-power consumption. The former is therefore the magnitude of the change of deflection produced by a given change in load power, and the latter is the power consumption in volt-amperes for a given magnitude of deflection. In commercial practice it is usually given as the apparent power in volt-amperes consumed by the instrument at nominal voltage and current and it is expressed as ohms per volt of the voltage circuit and volt-amperes of the current circuit. This therefore indicates the total power consumed

by the instrument in producing a torque to give full scale deflection.

The selection of an instrument for a particular purpose may require careful consideration with respect to its sensitivity, particularly where it is to be used for relatively low power measurements. In the more general application of a wattmeter, where power is taken from a voltage supply and measured, the consumption of the voltage circuit is of little importance to the user, but what may be of great concern is the voltage drop of the current circuit. Again, where the instrument is used for low power measurements in a network, to measure the power taken by a component of that network, the power taken by both circuits may be of equal importance.

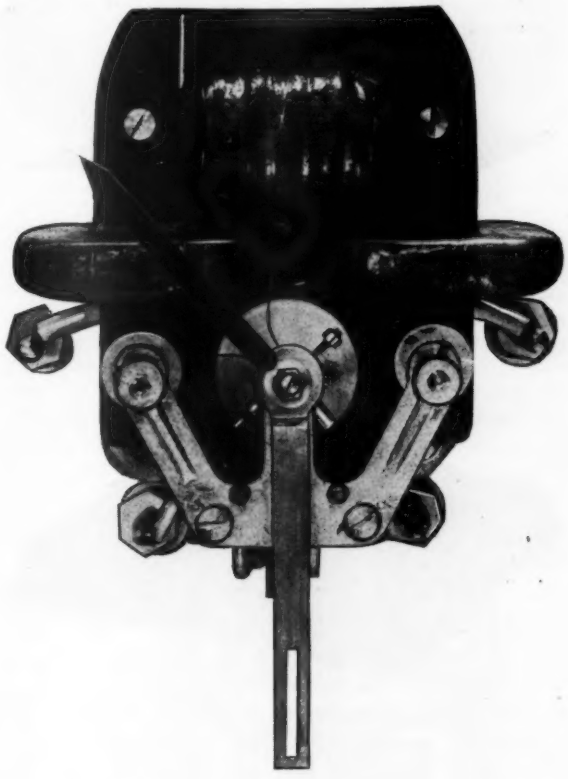
In general, the one instance when the power absorbed is of little importance is when the instrument is used as a standard for testing other instruments on artificial load; in this case accuracy and readability are of major importance.

Accuracy, readability and sensitivity are all interdependent and the ideal conditions are that the readability of an instrument should be better than the accuracy by a factor of not less than two, and that the power taken by the instrument circuits should not disturb the measured circuit conditions, so that the power to be measured with and without the instrument in circuit does not differ by an amount greater than half the accuracy of indication of the instrument, expressed in watts. This ideal can often be met by conventional types of wattmeter used on mains-supply frequency and where the circuit disturbance is due only to the instrument current circuit. One possible error which is not usually specified for a wattmeter concerns its accuracy when used to measure a non-sinusoidal voltage and current. In this case, the frequency error at the higher harmonics of the fundamental frequency is of importance where the power to be measured contains a large proportion of harmonic power.

There are two methods of connecting a wattmeter into circuit; the instrument voltage circuit may be connected either across the supply or across the load. In the former method, the power taken by the voltage circuit is not measured and the load impedance is increased by the instrument current circuit. In the latter, the power taken by the voltage circuit is measured by the instrument and the supply impedance is increased by the current circuit, which also carries, in addition to the load current, the current taken by the voltage circuit.

Corrections may be applied where the instrument losses are appreciable, but it must be remembered that these corrections may become complicated particularly where the load has a non-linear characteristic. Some instruments have compensating circuits so that no corrections are needed for the current taken by the voltage circuit.

The range of power measurement required to-day is from a fraction of a watt to many megawatts. Current and voltage transformers are extensively used on power frequencies where measurements at currents greater than 5 amp and at voltages greater than 750 volts are required. Both current and voltage burdens of the instrument may be of great importance to the user if the wattmeter is to be operated from transformers which have a limited rated burden and other apparatus is to be supplied by the transformers. For the majority of power measurements, wattmeters of various conventional types are available to the engineer. There are, however,



1 *3½ in induction type movement*

applications that require special consideration—particularly in the field of measurements at low voltage and low power. The use of negative-feedback amplifiers supplying one or both of the instrument circuits has been invaluable under these conditions.

Industrial Wattmeters

Industrial wattmeters undoubtedly constitute the largest class in service to-day, and include most switchboard instruments and a large portion of portable test-bench instruments. The modern demand for control-panel and desk operation has given preference to the smaller switchboard instruments of 3¼ to 4 in diameter. In this group of instruments three types are available: induction, dynamometer (with or without an iron core)

and thermocouple. Each type has advantages for particular applications, but a very broad technical distinction may be found in the ranges of frequency at which they are used. Induction instruments are restricted to the marked frequency in the mains-supply range, iron-less dynamometers may be used with both direct and alternating current up to 2500 c/s, and iron-cored dynamometers up to 500 c/s; the 3¼ in thermocouple type is used primarily for power measurement in aircraft at 400 c/s, although there seems no reason why it should not be employed at much higher frequencies.

The portable industrial test-bench group of instruments comprises both iron-less and iron-cored dynamometers, thermocouple instruments and (a fairly recent addition) the electrostatic wattmeter. Recorders for both switchboard and portable use are usually of the dynamometer type.

2 *3½ in iron-less dynamometer movement*

Based on the same principle as the induction watt-hour meter, the induction wattmeter may have one of two types of moving system. In one form this is a pivoted aluminium disc moving in parallel-pole gaps of electromagnets of similar disposition to those of the modern energy meter. In the other form the moving system is an aluminium cylinder; the movement of a novel instrument of this type is shown in Fig. 1 (p. 677). The magnetic circuit embodies an external U-shaped electromagnet carrying the voltage and power-factor compensation windings, and an internal core of cruciform shape, the current winding being on one of its polar projections. The spring-controlled cylinder is pivoted to turn in the air-gaps between the core projections and the poles of the outer magnet. The moving system is magnetically damped.

A 3½ in square-case iron-less dynamometer wattmeter is shown in Fig. 2; consideration here has been given to space saving in the design of this small switchboard instrument. The coils are rectangular with hemispherical ends instead of being wound in the conventional circular shape, and the space in the centre of the moving coil has been used for housing the lower control spring. The instrument has a single air-damping vane, and two wattmeter elements may be supplied, in the same size case, for polyphase circuits.

Fig. 3 shows a 3¼ in iron-cored two-element dynamometer of the long-scale type, with one field-coil assembly and the scale plate removed. The iron circuit is in laminated nickel iron, and magnetic compensation is provided to minimize the parasitic (or self-motoring) torque, common to this type of instrument. The damping is provided by two small permanent magnets embracing an aluminium disc mounted on the moving-coil spindle. The instrument has an external box containing the voltage resistances and power-factor compensation.

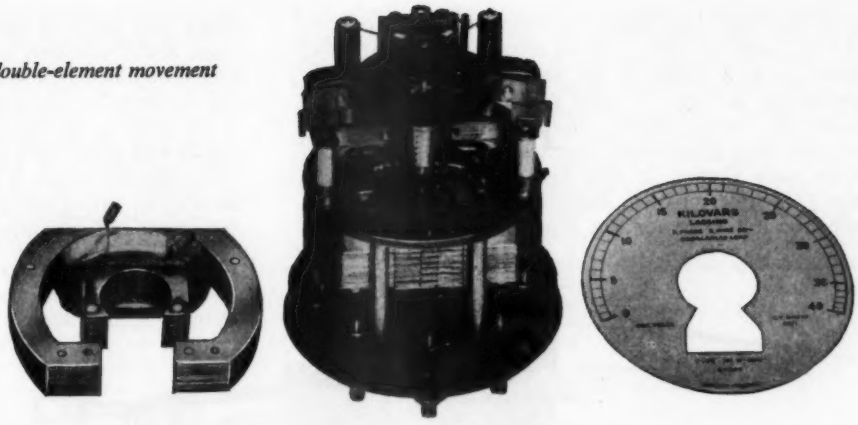
Two types of wattmeter, in addition to the dynamometer, are used for measurement in the higher-frequency ranges. First, there is the widely used thermocouple wattmeter. The circuit is conventional, using two thermocouples, the output indicator being a 6 in-scale-length d.c. millivoltmeter. The instrument is designed for use over a frequency range 50–5000 c/s and it has an accuracy of the order of $\pm 3\%$ full scale deflection. Secondly, there is shown in Fig. 4, the portable, suspension-type, reflecting, electrostatic wattmeter removed from its outer case and with the moving vane taken out of the quadrant assembly. The vane is made of mica, coated with a vacuum-evaporated layer of aluminium, and the quadrant

Characteristics of various wattmeters

Type	Number of elements	Deflection	Torque	Current circuit	Voltage circuit*
		degrees	g-cm	volt-amperes at 50 c/s	ohms per volt [4 VA]
3½ in induction..	1	280	0·14	1·0	
3½ in iron-less dynamometer	1	90	0·15	1·0	50
3¼ in iron-cored dynamometer	2	240	0·62	1·3	50
6 in thermocouple ..	1	—	—	1·0	166
5½ in electrostatic	1	14	$0{\cdot}15\times10^{-4}$	3·0	100
6 in iron-less dynamometer	1	80	0·16	1·0	50
7 in iron-cored dynamometer	1	100	0·08	0·5	167
6 in suspension-type reflecting dynamometer	1	35	0·006	0·25	750
3¾ in chart-recording, iron-cored dynamometer ..	2	28	20	7·5	38

* Values quoted are for instruments having a full scale deflection at a power factor of unity

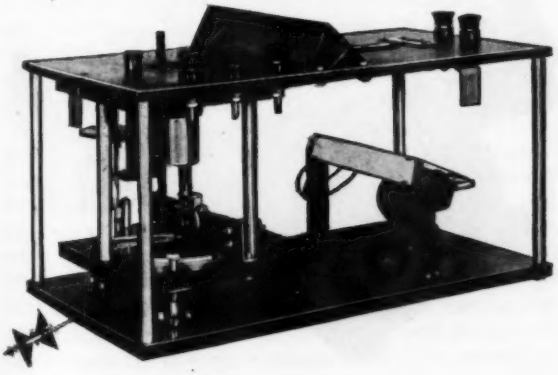
3 *3¼ in iron-cored dynamometer, double-element movement*



assembly incorporates a novel device for the balance of capacitance between the vane and each pair of quadrants. This instrument is inherently free from frequency-variation errors, over a very large range of frequency. The upper frequency is usually determined by the quality of the quadrant shunt and may be as high as 20 kc/s. A multi-range shunt, having a very short time-constant, is normally supplied with the instrument, giving it a scale range of 0·6–2000 watts in 10 steps.

Industrial types of wattmeter would not be completely reviewed without mention of a recorder. Fig. 5 shows a switchboard (or portable) 3¼ in-roll-chart recording wattmeter of the two-element, polyphase, iron-cored pattern. The field-coil assembly is made in two halves and clamped together to facilitate easy construction, one half of the lower element field-coil is shown removed in the picture. The field iron-circuit is of laminated silicon iron, while the core is of soft iron. The assembly is such that one, two or three elements can be built up as required in production, for single or polyphase wattmeters. The instrument is magnetically damped. Inherent power-factor errors due to the lag of the air-gap flux behind the magnetizing current are compensated by the addition of inductance into each voltage circuit.

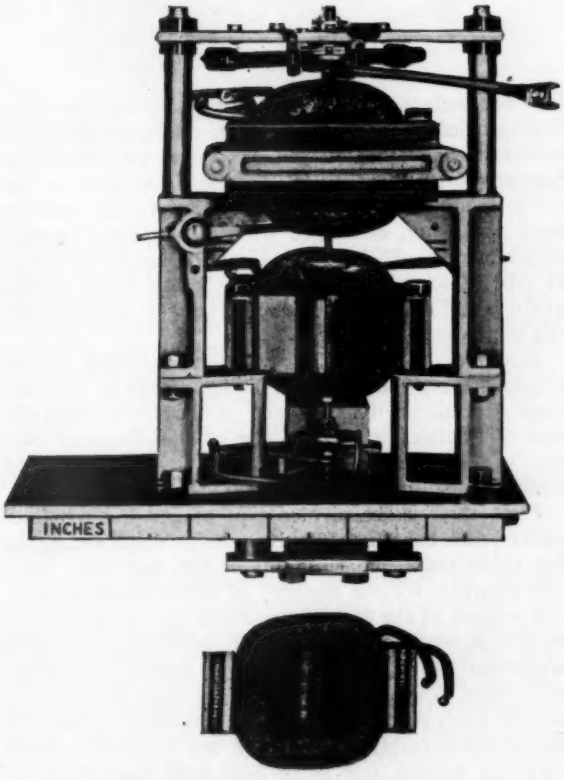
Torque and burden figures for typical wattmeters of the types described are given in the Table on p. 678.



4 *Portable electrostatic wattmeter*

Precision Wattmeters

The wattmeter in most general use in this class is the portable dynamometer, with a 5 or 6 in scale, conforming to B.S. 89: 1954. This instrument is extensively used as a substandard for checking industrial wattmeters (when the power may be produced artificially), but it is also used in many commercial and service laboratories, particularly those engaged on research and development,

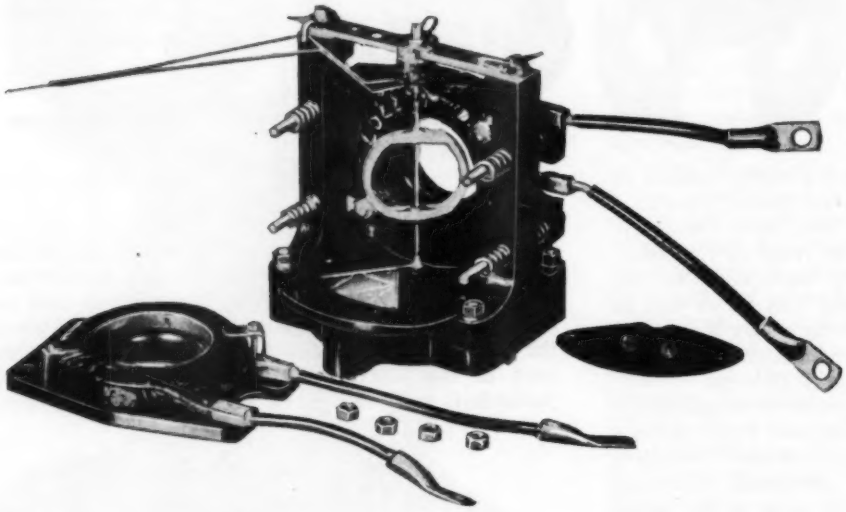


5 *3¼in. chart-recording, double-element movement*

as a test-bench instrument for real-power measurement. B.S. 89 gives only one grade of precision for a wattmeter having a scale length of not less than 5 in, this grading permitting a limit of error of 0·5% of scale range. However, many special instruments in current production have guaranteed accuracies as high as 0·1% of their scale ranges. In this higher-accuracy group are the 12 in-scale, pivoted, deflectional instruments, all of the iron-less dynamometer type. The wattmeter with a 5 or 6 in scale is also produced to a higher accuracy than that specified by B.S. 89, and is often used as an approved substandard for meter testing under the Electricity Supply (Meters) Act, 1936. Another instrument in the 0·1% group is the null-point suspension-type torsion-head wattmeter, developed from the original Siemens dynamometer, which was greatly improved by Drysdale in 1901. Later it was again improved and made astatic, and it is still in demand by many testing departments for use as a laboratory standard.

Examples of precision wattmeters described in this article are confined to three arrangements of the 6 in-scale deflectional dynamometer in current production, and it is noticeable that the aim of manufacturers over the years has been to improve sensitivity with respect to losses, and still maintain the accuracy.

First, there is the pivoted type of iron-less dynamometer which has changed only in design detail during the last thirty years, the sensitivity of this wattmeter being still adequate for the majority of power measurements. An example of the type of movement used in this instrument is shown in Fig. 6. This movement is from a portable wattmeter and shows the modern tendency to dispense with metal in the main assembly and thus reduce errors arising from eddy currents. The illustration shows the movement assembly out of its case, and with its concentric magnetic screens, one of its field coils and one of its dashpot covers removed. The base, dashpots, upright pillars and field-coil mounting are all of Bakelite. The shape and dimensions of the coils are such that a linear scale is obtained even with an 80° deflection of the moving coil. A common source of error with pivoted instruments of all types is the lateral displacement of the moving system with quite small disturbances from the horizontal. The movement shown is pivoted on spring-loaded jewels, the springs having sufficient tension to eliminate lateral movement and minimize levelling errors without causing stickiness through pivot friction. The wattmeter has a guaranteed accuracy of 0·25% full scale deflection over the frequency range 23–133 c/s. The instrument is also produced as a low-power-factor wattmeter giving full scale deflection at 0·2 power factor and it is compensated for the power consumed by the potential circuit.

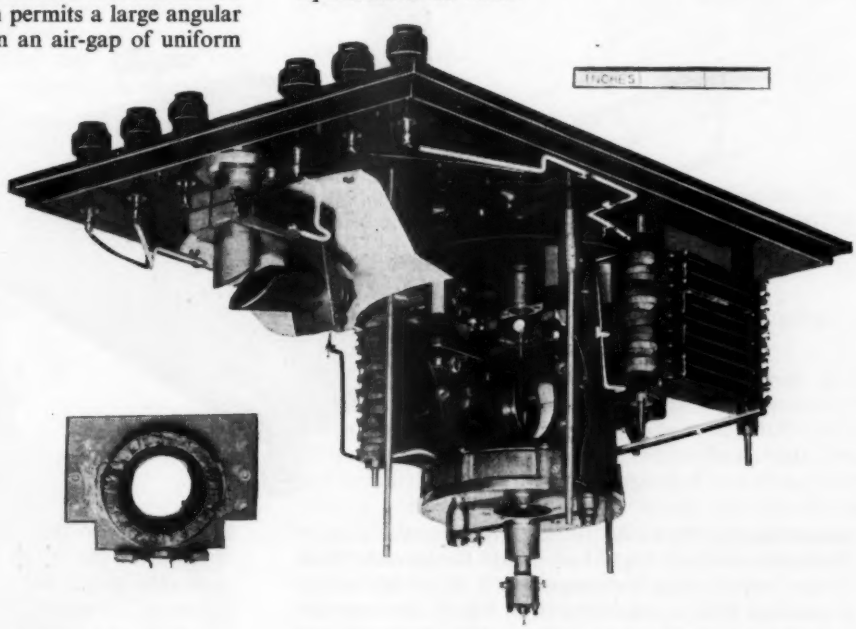


6 *Movement of a portable precision iron-less dynamometer*

7 *Movement of a portable precision iron-cored dynamometer*

Secondly, development following the introduction of nickel-iron alloys made possible the precision iron-cored wattmeter with its much improved sensitivity over the iron-less instrument. Although the use of iron introduces inherent errors additional to those found in the iron-less wattmeter, these errors are small in low-loss high-permeability iron and where not negligible they have been effectively compensated in instruments of modern design. Fig. 7 shows the movement assembly of the precision iron-cored wattmeter. The instrument has a core-type electromagnet with annular-ring flux return path, and the whole magnetic circuit is of thin laminations of nickel iron. This construction permits a large angular movement of the coil of 100° in an air-gap of uniform flux density, and the instrument has a linear scale approximately 7 in long. The total power consumed by this type of instrument for a given range is about one sixth that of the pivoted iron-less dynamometer and it has, therefore, a wider application in the field of low real-power measurement.

Finally, a further development of the iron-less dynamometer wattmeter has taken place within the last ten years, in the form of the taut suspension-type instrument with reflected light-spot image indication, and here again the sensitivity with respect to loss has been improved considerably. Fig. 8 shows a portable 6 in-scale suspension-type reflecting dynamometer with the instrument panel removed from its wooden case and viewed from the underside. The nickel-iron magnetic screen and one field coil have been removed and the sector-shaped, white scale plate cut away to show how the light-spot image is viewed through a scale opening in the top of the instrument panel above the scale plate. The moving coil is suspended by a double taut suspension and the mounting brackets are of high-resistance metal. The sensitivity with respect to loss is high, partly owing to the optical magnification which permits a much reduced angular movement of the moving coil for full scale deflection. The low power-consumption of the instrument enables it to be used for relatively low power measurements within a network, and extends the frequency range for these real-power measurements. An example of this is shown by instruments produced for service use over the frequency range 50–2 500 c/s, in which the lowest voltage range is 50 volts at 200 ohms per volt, the lowest current range is 200 mA, the maximum voltage drop on the current side is 1 volt at 2 000 c/s, and the full scale deflection is equivalent to 10 watts.



8 *Suspension-type reflecting, iron-less dynamometer wattmeter*

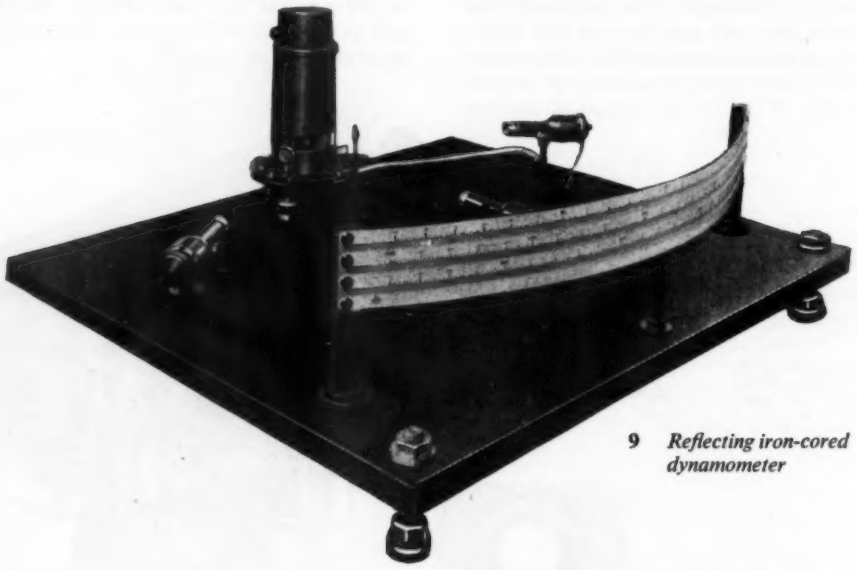
The instrument is viewed from a point below the level of the top panel, with the case removed.

Torque and burden figures for typical precision wattmeters of the types mentioned are given in the Table. The tendency to reduce control torques is an indication, particularly on modern precision instruments, of improved engineering design, resulting in higher sensitivity with respect to losses. The accuracy at these lower torques has been maintained only with the aid of modern production facilities, by concurrent reduction of the weight of the moving system, by improved pivoting or suspension of the moving coils and by improved efficiency of the field-coil system.

Standard Types

The national standardizing laboratories of various countries have developed wattmeters for their own use which have reading sensitivities of 0·01% of full scale deflection. These instruments are intended to be calibrated within a short time of each occasion of use, and long-term stability of calibration, although desirable, is not of the first importance. There are, however, two commercial types of standard wattmeter which have reading sensitivities comparable with that of the national

instruments and which are intended to be used by testing institutions equipped only with means of d.c. calibration. The accuracy claimed by the manufacturers for these instruments is 0·05% of full scale deflection. However, this represents a gain of only two to one over the best possible accuracy quoted for a normal pivoted wattmeter. It is an indication of the great difficulty in obtaining an accuracy appreciably better than 0·1% in normal measurements. However, the high reading-sensitivity of these instruments is a great advantage for accurate work.



9 *Reflecting iron-cored dynamometer*

The first of these instruments is a suspended nickel-iron-cored dynamometer shown in Fig. 9. The use of a three-lamp optical system makes possible the location of three parts of the scale under one another so that the great scale-length does not cause inconvenience to the observer. The full-scale point of 500 may be read easily to one part in 5000 and greater reading-sensitivity is possible with care.

The movement is suspended by a quartz fibre and the current is led into the coil by means of light metal ligaments. The iron-loss phase-angle error is compensated by means of resistance-capacitance networks. Series, series-parallel and parallel arrangements of the fixed coil-windings make possible four current ranges, and nine voltage ranges are also provided. The accuracy and stability of calibration of the instrument are limited by the mechanical characteristics of the suspension, including the current ligaments, and by the accuracy of adjustment, and by the temperature coefficient of electrical resistance of the resistors used for the voltage ranges and for power-factor correction. The weight of the movement is 1·5 g and it has an angular deflection of 90° with a full-scale torque of 0·007 g-cm.

The second of the commercial standard wattmeters is known as the a.c.-d.c. comparator. This is a null-point suspension-type instrument having an iron-less, dynamometer measuring-element and a permanent-magnet moving-coil control-element, the moving coils of both elements being mounted on the same spindle. A general view of the instrument removed from its case is shown in Fig. 10. In this instrument the a.c. torque is neutralized with a controlled d.c. torque, a method which eliminates most of the errors associated with mechanical control. Means are also provided for eliminating errors due to secular changes in the physical constants of the instrument. The magnitude of the direct current providing the balancing torque is determined by a potentiometer, for both d.c. calibration and power measurement. The dynamometer has low-current (50 mA) fixed-coil windings, and for power measurements the instrument is used in conjunction with a standard transformer having four primary-current ranges. Although it is a double-element instrument the natural period of the moving system is only four seconds. The reading sensitivity with rated voltage and current at a power factor of unity is 0·01% of the power measured, but the accuracy guaranteed is limited to 0·05% by manufacturing tolerances that include the accuracy of resistors, power-factor compensation and current-transformer errors.

Audio-Frequency Wattmeters

The frequency range of dynamometer wattmeters is limited by the phase angle between the current in the moving coil and the voltage applied to the voltage-circuit terminals. It is possible to extend this range somewhat by employing instruments with suspended movements having a low apparent-power consumption and by using compensating circuits. A further extension of frequency range is possible by the use of an amplifier to force the correct current through the moving coil. It may also be

advantageous to supply an amplifier for the fixed coil in order to avoid the circuit disturbance caused by the heavy power-consumption of this coil at high frequencies. The use of amplifiers makes power measurements with dynamometers practicable up to frequencies of the order of 20 kc/s. Difficulties then arise owing to the self-capacitance of the coils, to the time-constants of voltage-dividing resistances and current shunts, and often to amplifier limitations.

The use of voltage dividers and current shunts as primary components for measurement within a network may have limitations even at the lower frequencies, since these in conjunction with the amplifiers necessitate a common earth connection. Voltage transformers and isolating transformers with shunts can overcome this disadvantage, but here again the frequency range may be limited by the transformer errors.

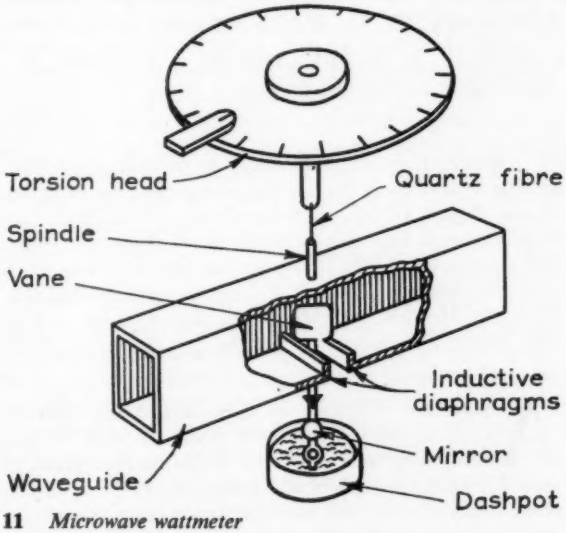
10 *Movement of the a.c./d.c. comparator*

The electrostatic and thermal wattmeters may be inherently more suitable for higher frequencies than the dynamometer but the difficulties with regard to resistance time-constants are present also with these instruments.

There does not seem to be any marked demand for power measurement at frequencies above 20 kc/s until very high frequencies are reached. In the frequency range of radiocommunication, power measurement is normally unnecessary since transmission is under tuned conditions and current measurements are accepted. In waveguide propagation, current and voltage have not an absolute meaning which can be defined by Ohm's Law, whereas power may be determined by an absorption device.

A Microwave Wattmeter

There are a number of methods of microwave power measurement, such as the water-flow calorimeter and those using bolometers, thermistors or thermocouples,



11 *Microwave wattmeter*

and to complete this brief review of power-measuring instruments, mention must be made of a commercial wattmeter for determination of power at 10 000 Mc/s. This instrument is the null-point torsion-head wattmeter and comprises a metallic vane suspended by a fine quartz fibre in a short section of the waveguide, the vane in the zero position being inclined at 45° to the broader walls of the waveguide (Fig. 11). The power to be measured, in flowing along the waveguide, exerts a torque on the reactive vane which is restored to its null position by turning the torsion head. The power flow is given in terms of the scaled angular rotation of the head by an expression involving the torsion constant of the fibre and the reactance of the vane. The former is determined by a conventional oscillation test by the addition of bars of known moment of inertia, the latter by a simple standing-wave measurement on a low-power test bench. These standardization tests involve measurements in terms of the primary standards of length, mass and time only; the wattmeter is therefore claimed to give an absolute measurement of power. The instrument can be used to measure the mean power of either continuous waves or pulses. A typical instrument has a full scale deflection equivalent to 2 kW (mean) with a lower limit (set by external vibrations) equivalent to about 100 mW. The torque on the vane at 2 kW is approximately 10^{-5} g-cm.

Acknowledgment

The authors wish to acknowledge the generous co-operation of the following companies in supplying photographs and technical information concerning the wattmeters mentioned: Nalder Brothers and Thompson, Salford Electrical Instruments, Sangamo Weston, Everett Edgecumbe and Co., Cambridge Instrument Co., and Elliott Brothers.

Journal I.E.E., November 1955

SIMULATORS

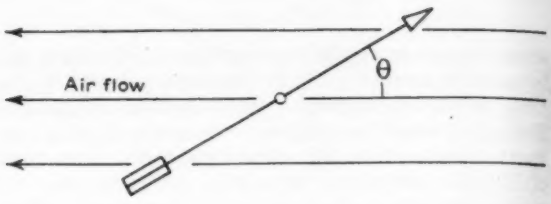
J. J. GAIT, M.A., B.Sc., *Associate Member*

Lt.-Cmdr. F. R. J. SPEARMAN, A.M.I.Mech.E., R.N.(Ret.), *Associate Member*

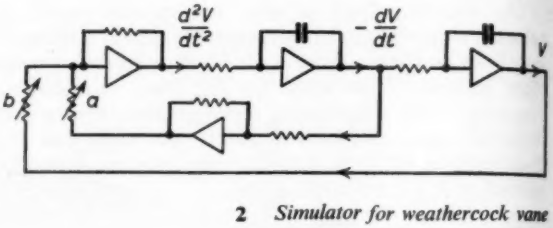
The following short article explains the purpose of machines such as Tridac, the giant analogue computer now operating at the Royal Aircraft Establishment. The authors have been intimately concerned with the development of Tridac, and a paper (No. 1899M) on the machine written by them in conjunction with Mr. A. V. Hemingway, B.Sc.(Eng.), Associate Member, and Mr. R. W. Hynes, B.Sc., will be read before The Institution on the 1st December, 1955.

A *SIMULATOR* may be defined and described in various ways. From one point of view, it is a computing machine, but from another point of view it is a working model which reproduces the dynamics of some real system. We consider the computing-machine aspect first by noting that there are two distinct types of computers—analogue and digital. The analogue type is based on the use of physical quantities, such as length, angle or voltage, which in the computer vary continuously in proportion to the variables of the problem. The simplest and most familiar example of this type of computer is the slide-rule, in which lengths proportional to the logarithms of numbers are manipulated. The digital computer, on the other hand, is based on combinations of units which are capable of counting discrete events and making simple logical decisions on such issues as coincidence of events. In the early machines the events utilized were such things as the kick of a ratchet riding on a toothed wheel; in the modern machines the events are electric pulses. Mechanical machines of both the analogue and digital types have been built for several generations culminating some years ago in the ball-and-disc integrator type of differential analyser and in the well-known commercial machines of the Comptometer and Hollerith types. The requirements of ballistics and other sciences during the war years and the advances in electronics which took place at that time brought about the rapid development of electronic digital machines with the result that to-day large electronic digital machines are available commercially for hire or purchase. The application of electronic techniques to analogue computers has produced equally rapid advances in these machines, and small electronic analogue machines are now also commercially available. At no stage has one type of machine removed the need for the other. It seems unlikely that this will ever be so, and it is fairly certain that there will always be problems more suited to solution by one type rather than the other.

The present-day digital machines tend to be general-purpose instruments which differ one from another mainly in the detailed design and in the type of "memory unit" employed. The analogue machines, on the other hand, are clearly divisible into different types, as, for example, simulators, electrolytic tanks, network analysers, etc. These divisions correspond either to the class of problem for which the machine is intended or to the physical quantity in which the analogue is expressed.



1 *Weathercock vane*



2 *Simulator for weathercock vane*

→ High-gain d.c. amplifier.

A simulator is an analogue machine which has been specifically designed to solve ordinary integro-differential equations with time as the independent variable. The reason for calling it a simulator rather than a differential analyser lies in the way in which it is used. A differential analyser is primarily an aid for the mathematician; it is a mechanization of the process of solution of differential equations. A simulator, however, is more in the nature of an aid to physicists and engineers in the sense that it is used as a working model of the system under investigation and it may be more convenient to study the behaviour of this working model, which obeys the same differential equations, than to study the real system. Thus, for example, should we be interested in the dynamic behaviour of a weathercock vane, we could make an electric model of the vane obeying the same equations of motion and then study the dynamic behaviour of this model.

A sketch of a vane is shown in Fig. 1. Owing to the restoring moment and air damping, the vane will, when disturbed out of the air stream, execute a damped oscillation as it realigns itself with the air flow. The appropriate equation of motion is of the form

$$d^2\theta/dt^2 + a(d\theta/dt) + b\theta = 0$$

Now, by using suitable feedback loops around high-gain directly-coupled amplifiers, an electronic system, as shown in Fig. 2, can be made to satisfy the equation

$$d^2V/dt^2 + a(dV/dt) + bV = 0$$

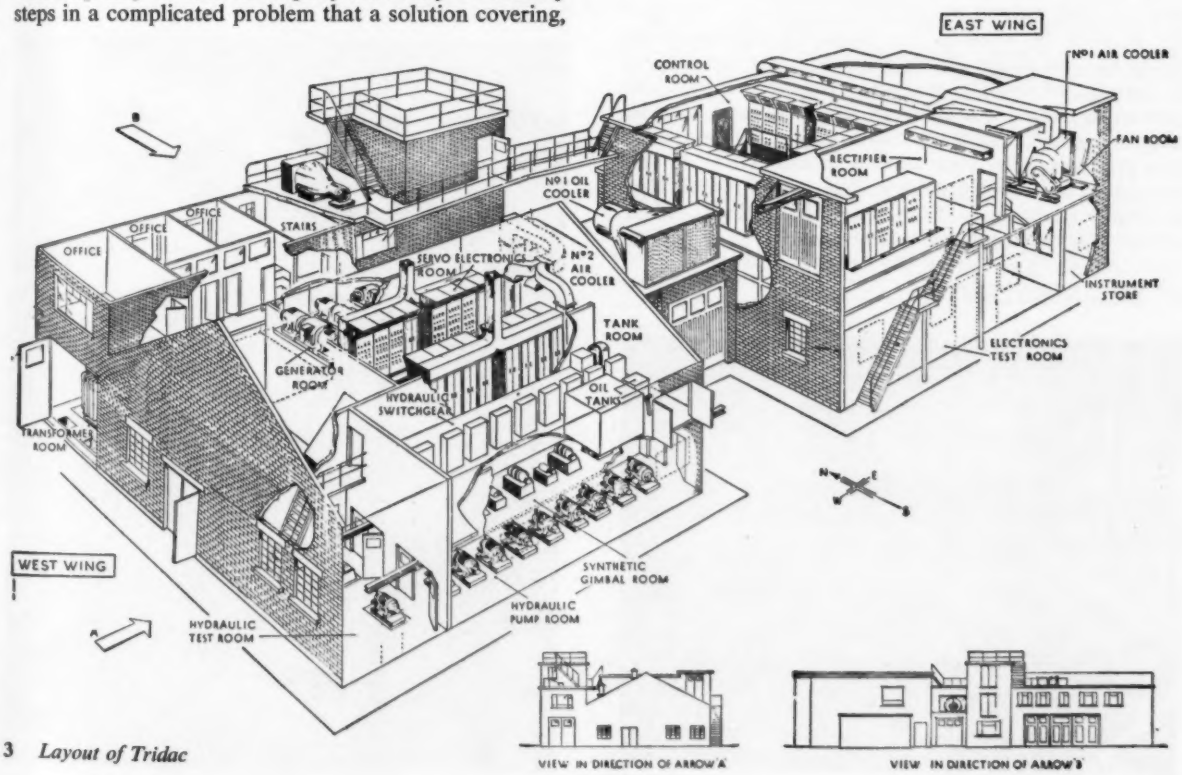
The value of this model of the vane, or simulator, lies in

the fact that the coefficients a and b can be readily and continuously varied, and the disturbances applied may be quite erratic, but a record of V and its derivatives will still show how θ and its derivatives would behave in the corresponding circumstances.

For such a vane it could be argued that it would be as easy to construct the real weathercock vane and try it. Such arguments, however, do not apply, for example, to determining the more complicated, but very similar, "weathercock" oscillations which occur during the flight of an aircraft or guided missile. Here the cost and uncertainties of full-scale trials are so high that the construction of elaborate and costly simulators is fully justified. For this reason the development of simulator techniques has largely been carried out by those associated with aeronautics. Now that small machines are coming on the market, however, there is little doubt that workers in other fields, even where the costs and hazards of full-scale trials are less, will seek the assistance of simulators.

The analogue machine cannot perform individual mathematical operations as accurately as can a digital machine, but high accuracy is not always the sole criterion on which to assess a simulator. This is especially true in problems, such as arise in aeronautics and elsewhere, where errors of perhaps 10% in the input information are not unusual. An important consideration is the speed of computation. A digital machine has, in general, to treat each problem step-by-step in serial fashion, and while each step may be executed rapidly there may be so many steps in a complicated problem that a solution covering, for example, say 10 sec of the flight of an aircraft or guided missile, may require several hours of computation. Electronic analogue machines, on the other hand, can perform all the operations needed in parallel with negligible time delays, and certainly for most aircraft problems they can operate so that the simulator model reproduces events on a true, or 1 : 1, time scale. Thus, if a specific manoeuvre of the aircraft occupies 10 sec, the simulator can reproduce this manoeuvre in 10 sec. Computational errors in the final answer of the order of a few per cent of full-scale are normally quite acceptable when, as has been indicated, the input data may not be known accurately. A great advantage of this real-time scale operation is that an admixture of real and simulated elements may be employed. A simulated "aircraft" may be flown by a real pilot if appropriate "instrument displays" and "cockpit controls" are provided; alternatively, a complicated servo system such as would form part of an auto-pilot may be used as part of the simulator. In this role the simulator becomes a form of test bed where components such as human pilots or auto-pilots may be tested under fairly realistic conditions.

For certain purposes it may be advantageous to have a simulator operate faster or slower than the real system it represents. Thus a real process lasting for hours may be reproduced in a matter of seconds for quick assessment; alternatively a very fast transient response may be slowed down to facilitate recording and study. A time



3 *Layout of Tridac*

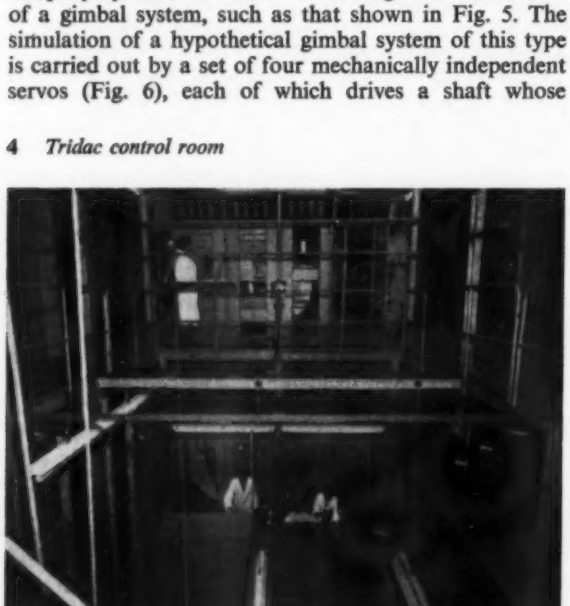
scale other than 1 : 1, however, precludes the incorporation into the simulator of any parts of the real system which are time dependent in their operation.

Electronic simulators vary considerably in their size and complexity, ranging from machines occupying a small rack to very large machines employing thousands of valves and requiring special buildings to house them. The largest simulator so far built in this country is at the Royal Aircraft Establishment, Farnborough. This machine (Fig. 3), known as TRIDAC (TRI-Dimensional Analogue Computer), is for the real-time-scale simulation of aircraft and guided-missile flight and, as its title implies, it is capable of simulating flight dynamics in three-dimensional space. In this simulation account is taken of the facts that the aerodynamic derivatives of the aircraft or missile are non-linear functions of altitude, speed, incidence, etc., and that, because of fuel consumption, the mass, the moments of inertia and the position of the centre of gravity are all changing. The bulk of the computing is in terms of direct-voltage analogies using high-gain drift-stabilized amplifiers. The "control room," which contains the greater part of the electronic equipment, is shown in Fig. 4.

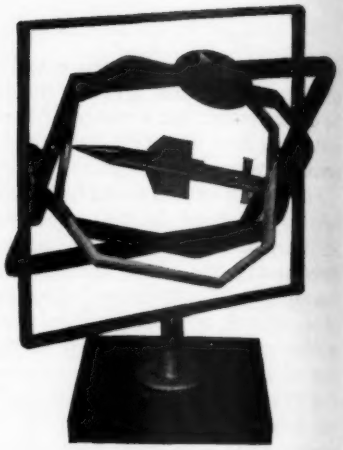
A major problem in the simulation of flight is that of axis transformation. The aerodynamic forces and moments are known only with reference to the aircraft axes, which are translated and rotated with the aircraft, while gravity forces are known only with reference to earth axes. To evaluate the motion facilities must therefore exist for making transformations of data from one set of axes to another. In Tridac the representation of the attitude of the aircraft or missile and the method of axis transformation are based on the fact that the aircraft or missile attitude relative to the earth may be uniquely specified in terms of the angles of the frames of a gimbal system, such as that shown in Fig. 5. The simulation of a hypothetical gimbal system of this type is carried out by a set of four mechanically independent servos (Fig. 6), each of which drives a shaft whose angular displacement equals that of one of the gimbal angles. These servos are hydraulically powered in order to give the high response rates required for real-time-scale simulation. The "synthetic gimbal shafts" drive, through special sine/cosine linkages, arrays of potentiometers which are used in the axis transformation networks.

It appears that the practical limits of accuracy are being reached in analogue machines, and that the next step forward in simulator development may well be the attempt to combine the accuracy of digital and the speed of analogue techniques so as to form a hybrid machine.

4 *Tridac control room*



5 *Gimbal system*



6 *Tridac hydraulic servos*

The Incorporated Benevolent Fund: Annual Report

THE following is the Report of the Court of Governors on the operation of the Incorporated Benevolent Fund of The Institution for the period 1st July, 1954, to 30th June, 1955. The Report, together with the Accounts, was circulated with the September *Journal*. Further copies can be obtained on application to the Honorary Secretary of the Fund.

Capital. On the 30th June, 1955, the capital of the Fund and "The Chesters" Trust stood at:

General Fund	£139833	(£138143)*
"The Chesters" Trust	£16662	(£16183)
	£156495	(£154326)

The income for the year from all sources for the Fund and "The Chesters" Trust amounted to £15821 (£15616) made up as follows:

General and Homes Funds		
Dividends, interest and rents	£2488	(£2678)
12708 subscriptions and donations	£12854	(£12427)
"The Chesters" Trust		
Dividends and Interest	£479	(£511)

The amounts raised in Local Centres by golf competitions, etc. (included in the above), have continued to give material assistance to the General and Homes Funds and although space does not permit mention of each of the Centres, the Court wish to thank especially the North-Eastern Centre for raising £458, the North Midland Centre £318, the Western Centre £196, the Mersey and North Wales Centre £165 and the Sheffield Sub-Centre £117. It is also gratifying to note that a number of organizations continue to give generous support to the Fund, including the Gramophone Co., Ltd., £189, and the Midland Electrical Engineers' Association, £150.

Subscription Income. The income from subscriptions has increased from £12427 to £12854. This amount is, however, insufficient to cover the expenditure and the Court appeal to those members who do not at present subscribe to make a contribution, however small.

Expenditure. The accounts show a small saving which is due to the non-recurrence this year of some exceptional expenses concerning the expansion of "The Chesters" estate. The cost of maintenance of this estate will now tend to rise, although this will be offset to some extent by the reduction of grants to those who become residents. The present cost of grants plus management and maintenance charges is £13151, which this year is not quite covered by the £12854 received from subscriptions and donations.

Legacies. During the year the Fund has benefited by the following legacies:

The late Mr. F. N. Haward	£300	0	0
The late Mr. W. Fennell	£173	5	0
The late Mr. R. Falshaw	£50	0	0
The late Mr. E. J. Wade	£20	0	0
The late Mr. R. B. Dennis	£15	0	0

In last year's Annual Report a legacy of £9179 1s. 9d. from the late Mr. B. E. Bolton was reported. A revised valuation of certain of the rent charges on the properties was subsequently admitted for probate purposes and the consequent reduction, amounting to £978, is shown in this year's Accounts. Reference was also made to a legacy of the late Mr. H. W. Hartridge. This included seven houses which have now been sold and the sum realized invested.

* Figures in brackets are those for the previous 12 months.

Grants. Grants were made to 133 beneficiaries and in assisting these persons the Fund also gave support to 111 dependants. The amount of these grants was £9092 and the average amount distributed per beneficiary during the year was approximately £68.

National Corporation for the Care of Old People—Crossways Trust, Ltd. The Fund still has beneficiaries resident in Trust homes at West Worthing, Englefield Green and Brighton, and this type of accommodation has proved particularly suitable for elderly people who are no longer able to cater for their own needs.

Local Honorary Treasurers. The Court wish to record their appreciation of the valuable work done by Local Honorary Treasurers in stimulating an interest in the Fund among the members of the Local Centres, and investigating applications for grants.

Refund of Income Tax. £1650 was recovered from the Commissioners of Inland Revenue owing to the kindness of members who subscribed by covenant. A total of £4500 could be saved if all subscribers of over 10s. per annum would use the covenant to subscribe for seven years, a procedure which involves no other obligation. Forms will be sent to any who will ask for them.

Homes Fund. The total amount received in subscriptions and donations from the inception of the fund to 30th June, 1955, was £35531, and in addition 225 members have signed deeds of covenant for the payment of subscriptions for a period of seven years. The sum expected from this source will bring the total to approximately £43000. The cost of the erection of sixteen houses, construction of the road and laying out of the grounds amounted to £59500.

"The Chesters." The amenities of the estate are enjoyed by beneficiaries who are resident there and the Court frequently receive from them letters of appreciation of the comfort and sense of security, combined with independence, which the estate provides.

Wilde Fund. Under the trust deed only full members and their dependants can benefit. On the 30th June, 1955, the Capital Account stood at £3048 10s. 2d., all of which is invested and brings in an annual income of about £93. The balance standing to the credit of the Income Account was £96 19s. A grant of £100 was made from this fund during the year.

Lord Hirst Fund. On the 30th June, 1955, the fund comprised:

Capital Account investments	£11543	3	10
Income Account investments	£3196	19	2

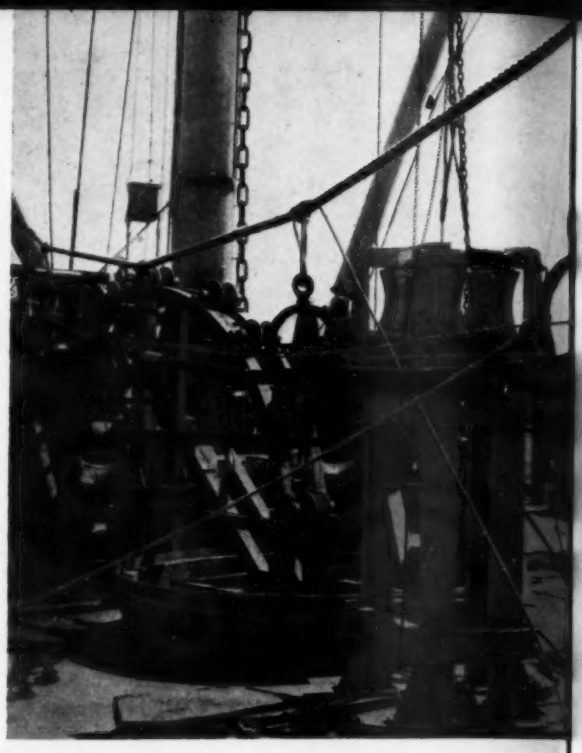
which produce an annual income of about £427. The uninvested balance of the Income Account was £180 5s. 4d. The object of the fund is to assist those men and women (or their dependants) who have rendered important services to electrical science, the electrical industry or electrical engineering, whether or not they are, or have been, members of The Institution. A grant of £130 was made from this fund during the year.

Journal I.E.E., November 1955

The Transatlantic Telephone Cable Project

LAYING THE FIRST CABLE

An account appeared in the January, 1955, issue of the Journal of the plans for constructing and laying a telephone cable system across the Atlantic. The system is to consist of two one-way cables between Clarenville in Newfoundland and Oban in Scotland, each cable including fifty-one submerged repeaters, and of a two-way cable between Clarenville and Sydney Mines in Nova Scotia with sixteen repeaters. It will interest readers to learn of the progress that has been made since that account appeared, culminating in the laying of the first cable from Newfoundland to Scotland during the summer and early autumn of this year. This cable will eventually carry the thirty-six channels transmitting speech in the west-to-east direction.



The first flexible repeater to be laid approaching the cable drum

IT will be recollected that the repeaters to be used on the main crossing of the transatlantic telephone cable are of American design, in which the valves and other components are contained in a long snake-like housing, sufficiently flexible to pass round the cable laying gear. The operational plans called for cable and repeaters to be joined together in continuous lengths of just over 200 nautical miles before loading into the cable tanks on the ship. This meant a very nice calculation. When the cable is lowered to the sea bed its attenuation changes, first because of the change in temperature and secondly because of the water pressure to which the cable is subjected. Exact calculation of these changes, based on laboratory measurements and backed up by the results of deep-sea trials, was necessary in order to ensure that the loss in each section of the cable, at its final location on the sea bed, would be matched by the gain of the repeater which followed it.

Laying started at Clarenville, Newfoundland. This little town, which does not appear on many world maps, stands at the head of Random Sound, an opening out of Trinity Bay. The bay has been the landing point of transatlantic telegraph cables for nearly one hundred years. The first 203 nautical miles of cable, armoured with heavy wire to withstand the hazards of the Newfoundland fishing-banks, were manufactured in the United States. The Post Office cable ship *Monarch* had loaded this cable in May and brought it to Clarenville. By proclamation it was a public holiday when the ship arrived and the scene was colourful, with representative flags, naval and military uniforms, and the bright red jackets of the attendant mounted police. At the ceremony initiating the actual laying operation, which was attended by Sir Leonard Outerbridge, the Lieutenant-Governor of Newfoundland, it was mentioned that this was the fourth "historic first" in transatlantic communication which the island had seen—the first telegraph cable, the first communication by radio, the first aeroplane flight and now the first telephone cable.

Cable laying started shortly after dawn on the 28th June, 1955, in perfect weather. At the entrance to Random Sound, there was the only unplanned deviation from the charted route; it was caused by a large iceberg. The first repeater was laid shortly after noon. Speed was reduced to about 2 knots and the repeater passed easily round the 7ft-diameter cable drum and thence over the bow sheaves into the water. Subsequently it was found that repeaters could be laid with the ship moving at about 3 knots. The normal speed of laying cable between repeaters was 6, and sometimes 7, knots.

This length of 200 miles was laid in just under a day-and-a-half and the end buoyed in 380 fathoms at the edge of the Newfoundland shelf. The *Monarch* then returned to the Thames to load 1287 nautical miles of cable weighing 4055 tons, nearly all with deep-sea armour required for laying in the depths—down to 2½ miles—between the edge of the Newfoundland shelf and the Rockall bank. The bulk of this cable had been made by a British firm, whose forerunners made the first submarine cable over one hundred years ago and who will manufacture most of the cable for the present project. The thirty-three repeaters had been flown from America and spliced into the cable at the appropriate distances apart. The *Monarch* sailed for the Clarenville buoyed end on July 30th, nine days ahead of schedule. The end was picked up; transmission measurement to

the shore ensured that all was well, and laying of the main section started uneventfully, although there was some anxiety at the time due to uncertainty about the course which hurricane "Connie" would follow.

During laying operations, the repeaters were continuously energized by power fed over the cable, the voltage being supplied by constant-current generators at the Newfoundland end and in the ship. Transmission measurements were also made continuously. These measurements enabled slight adjustments in the length of the cable to be made at the junctions between the 200-mile sections. Further corrections were made by splicing in equalizers in flexible housings similar to those used for the repeaters, to take care of variations in the attenuation over the transmitted frequency range. The joints between the 200-mile sections and for the insertion of the equalizers were made on the ship but, of course, had to be completed in time to avoid any interruption to the continuous laying process.

During the whole of the laying operations, uninterrupted communication was maintained between the ship and the terminal repeater station at Clarenville, by using short-wave single-side-band equipment. It was also possible to speak from Clarenville to the ship over the cable but not, of course, in the reverse direction.

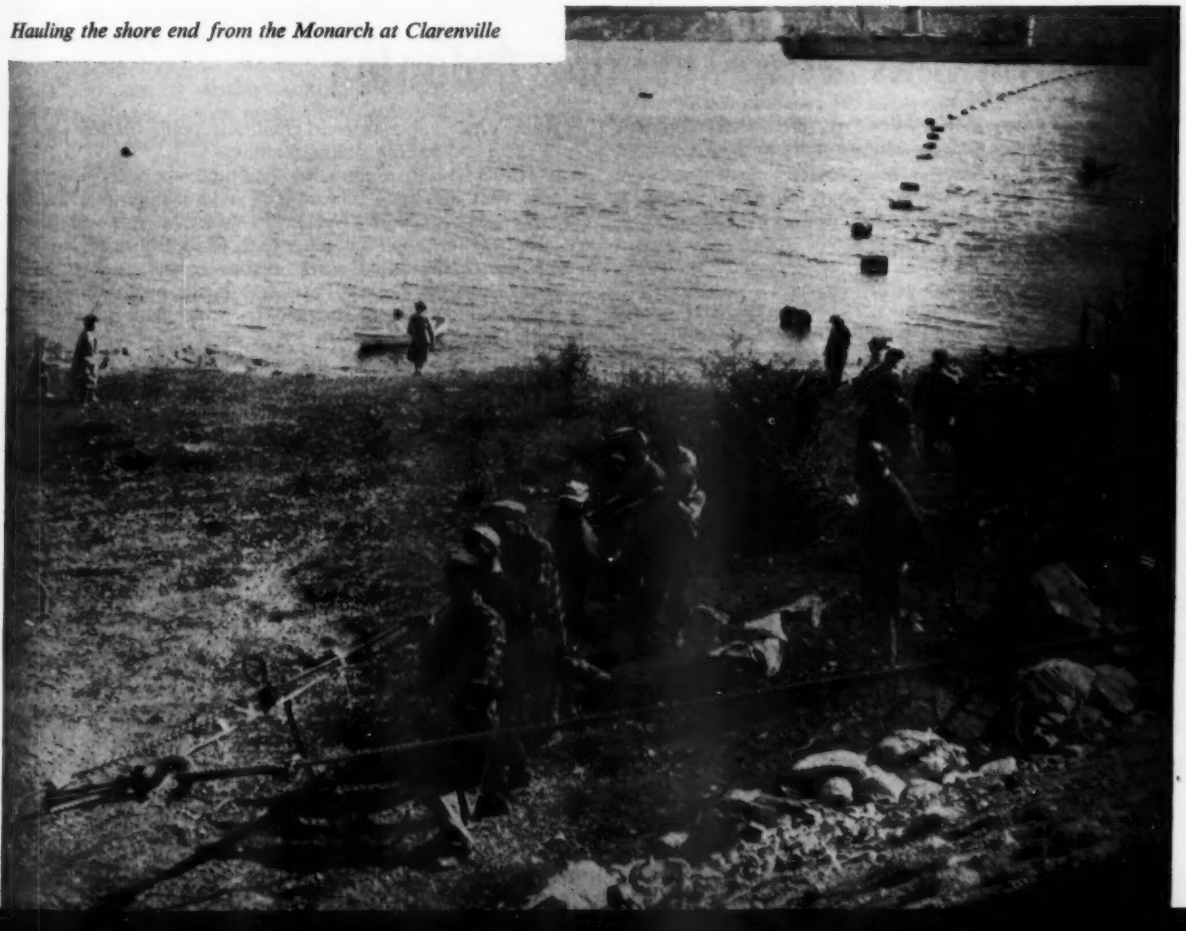
This laying operation took 8½ days and was mostly uneventful, but when the ship neared Rockall, a strong southerly gale was blowing and some difficulty was experienced in buoying off the end of the cable in 700 fathoms. A smaller cable ship would have had to abandon operations earlier.

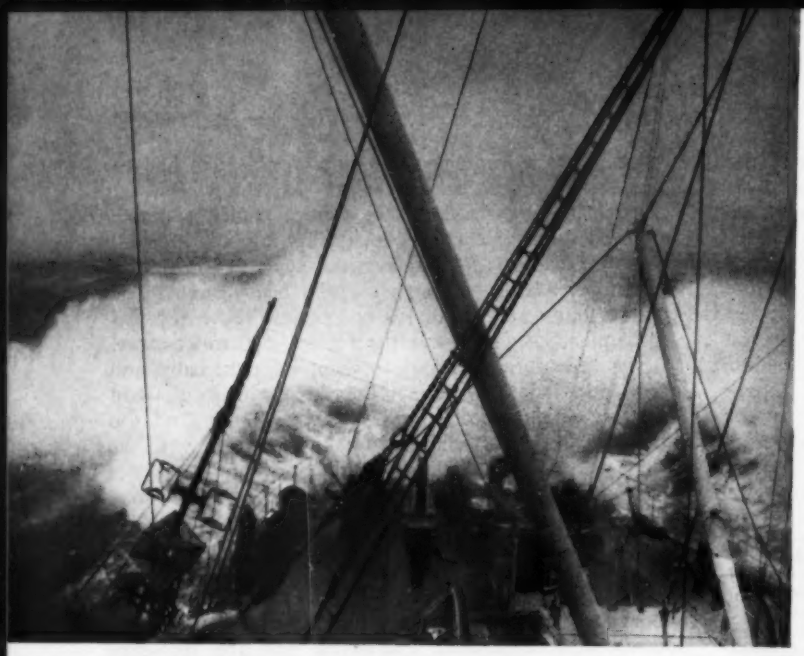
After loading the last 496 nautical miles of cable required to complete the connection from the Rockall bank to Oban, the *Monarch* arrived again at Rockall on September 17th in a rough sea and heavy swells. The marker buoy was missing. It had broken loose and was subsequently sighted near the Faroes, 500 miles away. It was, therefore, necessary to grapple for the cable and this operation was seriously interfered with by the bad weather which lasted from September 17th to 22nd. On the 20th, the wind increased to over Force 12 with the ship pitching and rolling heavily and shipping water fore and aft; the waves were 40ft high, and it was impossible to do anything but advance slowly into the wind.

The cable was hooked early on September 22nd, just over five miles from its end. As soon as it was brought on board the repeaters were energized and transmission measurements between Clarenville and the recovered end showed a change of attenuation of only 0·26dB, measured at 160kc/s (the total attenuation in the circuit was over 2000dB). This was very satisfactory.

After the necessary splice had been made, cable laying started again during the evening of September 22nd in a moderate sea. The weather worsened somewhat during the next few days, but the operation was completed without further incident and the *Monarch* entered the Firth of Lorne shortly after dawn on September 26th.

Hauling the shore end from the Monarch at Clarenville





The Monarch weathering the hurricane off the Rockall bank on the 20th September, 1955

A two-mile length of cable had already been laid out from the shore by a smaller ship and the end buoyed. This was picked up and the final splice made on the fore deck of the *Monarch* during the day. After the usual stringent mechanical examination of the joint, including an X-ray inspection of the moulded polythene core, the final splice was slipped at 1730h G.M.T. and Europe and America were connected for the first time by telephone cable.

The final scene lay in the repeater station at Oban the same evening, when power was applied to the completed cable. The operation of raising the direct voltage across the cable to the full 4000 volts, with the load balanced between the constant-current generators at each end, was a lengthy one, but it was completed at last and transmission tests began. To the satisfaction of the large groups of British and American engineers gathered in the station the early measurements showed that the noise level was substantially below that allowed for in the specification, and that the overall attenuation was very close to the predicted value throughout the frequency range.

Only fifty-one repeaters have been used for this crossing instead of the fifty-two which the previous article suggested would be necessary. Measurements made just before laying began indicated that it would be possible to increase the length of cable between adjacent repeaters by about $\frac{1}{4}$ mile. In addition some miles have been saved from the charted route by omitting a proposed detour round an area where the ocean bed had been suspect.

This work completes the first phase of a not inconsiderable engineering achievement.

Telecommunication in the Colonies

IN recent years the progress of general development in the Colonies has quickened almost phenomenally. Stimulated by the large amounts—totalling some £120 000 000—provided by the United Kingdom Treasury under the Colonial Development and Welfare Act of 1945, which were intended merely to prime the pump, capital expenditure and commercial development are now occurring at a rate which fifteen years ago would have been considered incredible. Every form of transport—roads, railways, shipping, air services—has had to be expanded rapidly to cope with the increased trade, and, as telecommunication engineers will readily appreciate, all this has entailed a corresponding expansion in telecommunication services, to allow the expansion in industry and commerce and in other forms of communication to be fully effective. This applies equally to internal and external communication.

But, as in other forms of development, it is not only money and materials which control the rate of progress but also the professional and technical staff required for construction, operation and maintenance. The engineering staffs of telecommunication departments are being expanded and existing staffs have achieved almost unbelievable progress for their numbers, but the rate of recruitment is slower than the demand and there are still excellent opportunities for professional engineers with experience. The field of activity is wide, embracing every kind of telephone and telegraph technique, and the installation, operation and maintenance work, often under tropical conditions, calls for the exercise of great engineering skill and ability.

Throughout the Colonial Empire multi-channel operation—both v.h.f. and line—is being used and a number of automatic exchanges are already working. Teleprinters are being introduced for telegraph handling. In Nigeria, for example, plans for the expansion of services, costing between £16 000 000 and £25 000 000 for the Posts and Telegraph Department as a whole, have been accepted in principle by the United Kingdom Government. In all the larger Colonial territories there are plans for the development of telecommunication on the same lines, which vary in extent according to the territory.

The general requirement is for engineers with experience of h.f., v.h.f. and u.h.f. radio systems, transmission, exchange systems and telegraph systems of advanced design. Many people still have the impression that the standards of professional engineering in the Colonies are low and that living conditions are rough and dangerous, but whatever may have occurred in the past this is no longer true. The young colonial engineer is to-day called on for a high standard of professional ability and can in general expect to have to shoulder a greater individual responsibility than is usual in older and better-developed countries. Living conditions in the larger towns are good and medical facilities are excellent, while for those with a spirit of adventure there is still scope in the less developed areas.

Journal I.E.E., November 1955

Valve Life

By G. H. METSON, M.C., Ph.D., M.Sc.,
Associate Member

Despite the recent development of the transistor it is likely that the thermionic valve will continue to be the mainstay of the electronic industry during the foreseeable future, and its use is becoming even more widespread. The importance of designing and manufacturing more reliable valves is therefore greater than it has ever been. In this article Dr. Metson, of the Post Office Engineering Research Station at Dollis Hill, London, reviews recent work on the causes and remedies of valve failure. The article is based on a paper[1] entitled "A Study of the Long-Term Emission Behaviour of an Oxide-Cathode Valve," which was published in the September issue of the Proceedings, Part B.

THE growth of activity in electronic engineering during the past ten years has stimulated interest in the life and reliability of thermionic valves—literature on the subject during the past five years probably exceeds that of all previous time. Despite recent progress, however, the problems of valve failure are still only partially understood, and the present article attempts no more than a broad appreciation of the art as it appears to stand to-day.

The valve most commonly used in general electronic work is the high-vacuum indirectly-heated oxide-coated-cathode type in diode, triode or pentode form. In the interests of efficiency such valves have tended to become smaller in physical size and more economical in heater power—the four-watt cathode, so prevalent in the Second World War, is now displaced by the two-watt version with little change of valve performance, and the trend has not yet ceased. There can be little doubt that this steady improvement of performance has made the task of increasing life rather more formidable.

"Valve failure" is a generic term and covers all changes in the valve of sufficient magnitude to cause intolerable changes in the external circuits. It has become fashionable to separate these changes into two classes—mechanical failure and electrical failure. Generally speaking, mechanical failure is characterized by abrupt cessation of valve action whereas electrical failure is more in the nature of a decay phenomenon. The two forms carry different weight in different spheres of use; the mechanical form is fearful to the aircraft engineer whilst the communication engineer is more concerned with the decay phenomenon with its insidious and indefinite approach to an end point. They are, however, not always clearly distinguishable and there are known conditions under which mechanical faults cause electrical failure, and vice versa.

Mechanical Failure

Perhaps the most marked characteristic of mechanical failure is its enhanced probability of occurrence when the valve comes under mechanical load. The increasing use and importance of valves in mobile stations on land, at sea and in the air have therefore led to a first concentration of effort on mechanical failure. This work has been pressed forward with great vigour since the war, and a short range of common-usage valves of inherent mechanical reliability is now becoming available. Progress has been made along two general lines—a study of the basic properties of materials affecting mechanical reliability and a thorough-going investigation into the relation of structure to strength under conditions of shock and vibration. Notable papers on these advances have been written recently by O'Donnell Roberts[2] and by Rowe and his associates.[3]

Electrical Failure

Whilst the main effort has so far concentrated on mechanical failure, the electrical aspects have not been altogether neglected and some modest but sound progress can be reported. Electrical failure covers a variety of forms and the simultaneous presence of several such factors in a valve has led to confusion and difficulty in interpretation. Perhaps the most solid achievement during the past ten years has been the development of techniques for separating and measuring these effects in such a way that it is now becoming possible to relate individual effects to particular causes. It is becoming clear, for example, that most electrical faults in a valve originate from microchemical actions in the oxide-coated cathode itself. The present section will attempt to outline the broad nature of these actions.

The cathode consists of a granular matrix of barium and strontium oxides deposited on a hollow metallic core which contains the insulated heater. The essential electron flow must therefore pass from the core into and through the matrix and out again into the vacuum. The hot matrix must therefore conduct and emit electrons in adequate quantity and it can do so only if it contains an excess of the metal barium. From the point of view of useful valve action a perfect lattice of barium and strontium oxides is a non-conductor and non-emitter but adulteration of the lattice with a trace of metallic barium renders it a strong conductor and excellent emitter. The basic problem of cathode life is therefore the initial provision and subsequent maintenance of an adequate level of excess metallic barium. The source of barium is clearly the molecular matrix itself and this must be split by removal of the oxygen atom. There are two obvious ways of effecting the split—by the introduction of elements chemically capable of wresting the oxygen atom from the oxide molecule, and by direct electrolysis of the molecule. Extensive use of the first method is made in common valves, and typical reducing agents employed are magnesium and silicon, which are included as activators in the nickel core metal. The reactions involved are:

$$Mg + BaO = MgO + Ba \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$Si + 4BaO = Ba_2SiO_4 + 2Ba \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Since the activators are limited in quantity and perform chemical work they are subject to inevitable decay. A cathode wholly dependent on activators for its excess barium is therefore living on capital and must fail in time owing to lack of emission. It is at this stage that the electrolytic mechanism becomes important as, depending only on current flow, it continues supplying the essential barium. An obvious question now arises—why not rely wholly on electrolysis and dispense with the reduction method and its attendant decay? The answer is an economic one. The price of a valve has a direct relationship to the quality of its vacuum and most valves in common usage enter service with an undesirably high level of residual gas content. Under the action of the getters this high initial residual pressure falls with time but during this early period of life the excess barium in the cathode is open to destruction by gas oxidation. It is the prime duty of the activators to nullify this attack by matching a destruction with a production rate. Ideally, the two rates should balance each other to extinction over a period of time, leaving the mild electrolytic action to the long-term task of supplying excess barium to the matrix. If the valve is provided initially with a vacuum of sufficient quality it is possible, of course, to dispense with the activators, but such valves can at present be produced only at high cost. This description of cathode action is over-simplified but the author hopes that it will suffice for the purpose of understanding the principal causes of electrical failure in valves.

The decay of mutual conductance with time is probably the most serious of the electrical forms of failure. It is due to two separate and distinct causes—oxidation of excess barium in the cathode leading to emission failure, and growth of a high-resistance interface between matrix and core. The first cause is clearly the destruction rate of barium by residual gas exceeding the production rate by the activators over a sufficient period of time. Symptoms of failure are a fall in mutual conductance and an increase in valve noise due to inadequate emission. The second cause is the formation of a layer of barium orthosilicate between matrix and core during valve manufacture—the chemical reaction will be clear from eqn. (2). When the valve enters service the layer is highly active owing to the presence of excess barium atoms and its resistance is normally less than an ohm. As the layer loses excess barium by gas action or diffusion to other parts of the matrix, its resistance rises and may reach 50 or even 150 ohms for a two-watt core. The negative-feedback action of this resistance results in substantial degradation of mutual conductance. These two actions are at present thought to account for most cases of mutual-conductance failure.

Most other causes of electrical failure are connected in some way with the evaporation of active metals such as magnesium and barium from either anode or cathode. During manufacture and under operating conditions some evaporation of barium oxide occurs and results in the formation of barium-oxide films on the mica insulating surface of the electrode structure. These films have little effect until they become activated by barium evaporated from the cathode or magnesium from the anode. On activation the films show conductance and give rise to a considerable range of valve troubles—leakage between electrodes causing intermittent noise, growth of inter-electrode capacitance, etc. Most of these evaporation effects can be avoided by shadowing the surfaces of the insulators from anode and cathode, and such methods will doubtless be used as new valves are designed.

Natural Life Span

Almost all valves fail in service from causes which appear to be capable of remedy. If the core material is designed to avoid interface-resistance growth, if the structure is freed from all residual gas, and if steps are taken to avoid contamination of insulating surfaces, the valve should run for a natural life-span which is based on some fundamental property of the cathode material used; in short, life should be predictable and calculable. At present the art is far removed from this desirable state and the best that has been achieved is to show that the length of life does in fact increase as we approach the conditions outlined above.

In a recent paper[1] an attempt has been made to survey this problem of natural life. It is assumed that life will continue so long as an adequate amount of oxide remains on the core and this oxide retains a sufficiency of excess barium metal. The rate of loss of the oxide itself by thermal evaporation is calculable and twenty years of running at the conventional cathode temperature should have little material effect on the gross bulk of the matrix. The real problem therefore hinges on the continued ability of the matrix to maintain an adequate level of excess barium within its lattice. This aspect is examined in some detail in the paper, which comes to the tentative conclusion that electrolysis of the matrix takes place at a sufficient rate to keep it adequately stocked with excess barium metal. The oxygen gas continually drawn from the cathode as an electrolytic by-product must of course be prevented from returning to the cathode; otherwise the whole electrolytic activation will be negated. If such preventive arrangement can be made and if no other residual gases are generated during operation there appears to be reasonable hope that valve life may be indefinitely prolonged. The main obstacle at present is the technological difficulty of maintaining an adequate vacuum during normal operation.

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2 O'DONNELL ROBERTS, E. A.: "A Study of Some of the Properties of Materials affecting Valve Reliability," *Proceedings I.E.E.*, Paper No. 1645 R, February 1954 (**101**, Part III, p. 197).

3 ROWE, E. G., WELCH, P., and WRIGHT, W. W.: "Thermionic Valves of Improved Quality for Government and Industrial Purposes," *Proceedings I.E.E.*, Paper No. 1740 R, December 1954 (**102** B, p. 343).

Supply Section

SUMMER VISIT TO HOLLAND

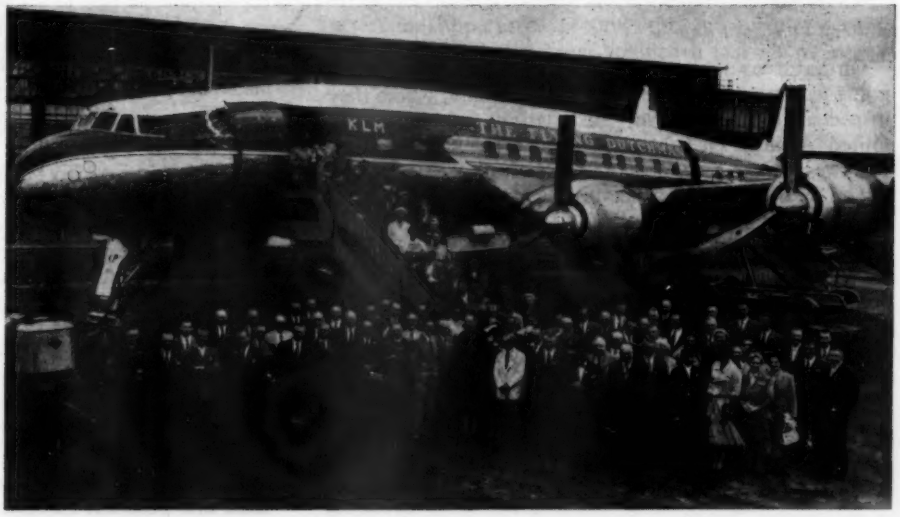
A Tradition Revived

MR. J. D. PEATTIE, Chairman of the Supply Section, led a contingent of about 140 members and their ladies to Holland on the 8th September, 1955, for the annual Section Summer Visit. The custom of the Section of having summer meetings on the Continent, which was interrupted after the visit to Belgium in 1938, was thus renewed. Most of the party travelled by boat on Thursday evening and returned to Harwich on Monday morning, but a number of others gained a day by flying from London, and some combined the visit with holidays or business across the North Sea and joined the main party *en route*. The headquarters for the visit was the Grand Hotel Krasnapolsky, Amsterdam.

A Visit to Arnhem

The principal excursion from Amsterdam was an all-day visit on Friday to the neighbourhood of Arnhem. The members of the Supply Section spent most of the morning at the laboratories of the Inspection Board of Electrotechnical Materials (KEMA), while their ladies toured the National Park "de Hoge Veluwe." In the afternoon both the members and their ladies visited the KEMA testing and demonstration rooms devoted to domestic equipment and appliances. Professor van Staveren, the Director, who was already well known to many, welcomed members to the laboratories and said how pleased his countrymen felt that the first visit of the Supply Section to the Continent after the war should be to Holland. He briefly described the constitution of KEMA, which is a testing organization set up by the voluntary association of the electricity supply undertakings—municipal and company-owned. Although a large amount of the work carried out is on behalf of the electricity supply industry in Holland, much is also done for other Dutch organizations and for those of all European countries west of the Iron Curtain. Members saw, for example, an exhibition of short-circuit testing on a unit of switchgear of a well-known English manufacturer. Professor van Staveren was also proud to say that the original designs of all equipment of Continental manufacture intended for use in Canada had to be approved at his testing station. Most of the testing work for Dutch authorities, on such items as meters, the conditioning of boiler feed-water, and the calorific value of fuel, is carried out in the laboratories of the manufacturers or electricity works, but high-voltage and short-circuit testing are done by KEMA. The capacity of the station will shortly be raised to enable it to carry out all tests required by B.S. 116: 1952 on switchgear rated up to 7500 MVA at 275 kV.

In addition to the testing station the site accommodates the national control room, which supervises the load dispatch at 150 kV for all the electricity supply undertakings in Holland and also the export or import of energy at 220 kV to and from Belgium and Germany. The transfer of electricity abroad depends on the availability of cheap water power in Germany, and is controlled to give the best overall economic results.



Members and their ladies during the tour of Schiphol

Mr. J. D. Peattie laying a wreath at the Arnhem Memorial on behalf of The Institution

The testing station is also carrying out some original research on homogeneous-suspension type nuclear reactors—aided by the use of enriched uranium from England—and members were able to inspect this work. As a result of these researches it is hoped that small, compact and safe reactors will be developed for "pocket" power stations in sparsely populated areas.

A "coffee table" lunch was served in the KEMA canteen and the English visitors followed their hosts' lead in dealing with a typically Dutch midday meal.

While in the Arnhem area the party visited the "Airborne" Cemetery at Oosterbeek, where the Chairman laid a wreath on behalf of The Institution. They also went to the memorial which has been erected by the Dutch at Oosterbeek at the site of the most severe fighting, and heard at first hand some of the tales of heroism of soldiers and civilians in the Battle of Arnhem in September, 1944.

A Very Full Saturday

On Saturday the party divided into two groups, one going to Schiphol, the airport of Amsterdam, where they inspected the engineering installations of the Royal Dutch Airlines (K.L.M.), and the other going to the Hemweg power station of Amsterdam.

Led by Ir. J. Luymes, Vice-President of the Engineering and Maintenance Group of K.L.M., the first group saw the workshops, testing laboratories, maintenance hangers, training centre and stores necessary to keep 85 air-liners flying for an average of eight hours a day. It was a visit which should inspire confidence in any reluctant air traveller. His safety and creature comforts are the first considerations of this famous airline. After the visit, the group were entertained to lunch in the large K.L.M. canteen, and Mr. L. Drucquer thanked Ir. Luymes for his kindness, remarking with a smile, "Never have so many questions been asked by so few. . . ."

The second group heard a description of the Hemweg power station from the Director, Ir. L. Vos. The power station is of modern design, without unnecessary frills, and is economical in construction and running costs. In a brief speech after lunch, Mr. Peattie complimented Amsterdam on the ownership of such a power station.

The afternoon was free for visiting the shopping streets of Amsterdam, and, as on all the days of the visit, the weather was warm and sunny. The whole town seemed to be out shopping—the shopkeepers take their half-day on Monday morning, not Saturday afternoon.

On Saturday evening there was an informal dinner-dance, to which the visitors' hosts and guides were invited. In a humorous speech, Mr. Peattie paid tribute to the way in which the Supply Section had been received in Holland and to the great amount of work done by helpers in London and Amsterdam to make the visit a great success. The Netherlands Railways were thanked not only for the excellent travelling arrangements which they had made but also for allowing members to play at stopping their trains without paying the usual penalty of £5. Some small gestures of appreciation were distributed to the Dutch ladies and light-hearted responses were made by Ir. Bonebakker, Chairman of the Electrotechnical Division of the Netherlands Royal Institution of Engineers (K.I.I.), and Mrs. Bonebakker.

A Tour of Amsterdam

On Sunday the whole party went in two water-buses for a tour of part of Amsterdam's 60 miles of canals—a most impressive tour, made all the more interesting by the vivacious running commentaries of guides who knew their Amsterdam well. At night some of the canals and bridges are outlined with electric lights and many members made another tour to see these illuminations.

Ir. L. Vos talking to Miss E. F. Hansford during the canal cruise

In the afternoon, after lunch at the Amstel Hotel on the riverside, the party went to see the famous works of art in the Dutch National Museum. The throng of sightseers of many nationalities added a cosmopolitan touch to the visit.

On Sunday evening the Council of the Royal Institution of Engineers entertained the members of the Committee of the Supply Section and their ladies to dinner at their Institution building in The Hague. This delightfully informal meeting gave the committee another opportunity of saying how much the Section had enjoyed their first post-war Continental Summer Visit. G. S. B.

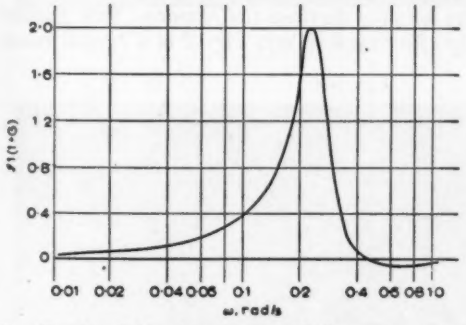
DIGESTS of Papers in the Proceedings

Transient Response

A digest of a Measurement and Control Section paper (No. 1907) entitled "An Approximate Method for obtaining Transient Response from Frequency Response," by H. H. Rosenbrock, B.Sc.(Eng.), Ph.D., Associate Member. The full paper is published in November, 1955, in Part B of the Proceedings.

THE DESIGN OF SERVO MECHANISMS is usually carried out by considering the way in which they respond to steady sinusoidal inputs. On the other hand it is very useful to know how a given servo mechanism will respond to a sudden change or step in the input. It has been known for a long time that the step or transient response can be obtained from the frequency response, provided that the system is stable and linear, but no very convenient method has been available for carrying out this transformation.

The frequency response of a system, when expressed in complex notation, has a real and an imaginary part. In the method described in the paper the imaginary part of the response is plotted against a logarithmic scale of frequency. A transparent cursor is then placed over the graph of the imaginary part and moved to right or left until the appropriate time is shown on a horizontal scale. The intercepts of the imaginary part on a number of vertical scales on the cursor are then added, and the result is a point on the step response for the chosen value of time. By shifting the cursor to right or left further points on the step response can be obtained. Figs. 1 and 2

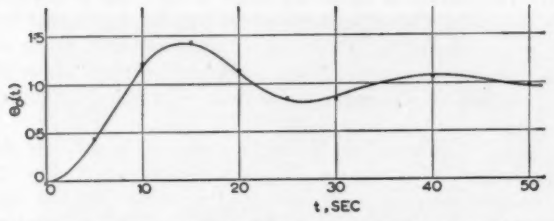


1 *Graph of imaginary part of frequency response for a particular servo system*

show respectively the imaginary part for a certain servo system and the corresponding step response.

An important result of the method is to show that the imaginary part of the frequency response contains information about the step response in a readily accessible form, and can therefore occupy a pivotal position in the design procedure.

The use of the cursor is not confined to servo systems. It can be used to obtain transient responses for any system governed by a linear differential equation with



2 *Step response corresponding to the imaginary part shown in Fig. 1*

The curve is based on calculated values, and the crosses show points obtained by means of the cursor.

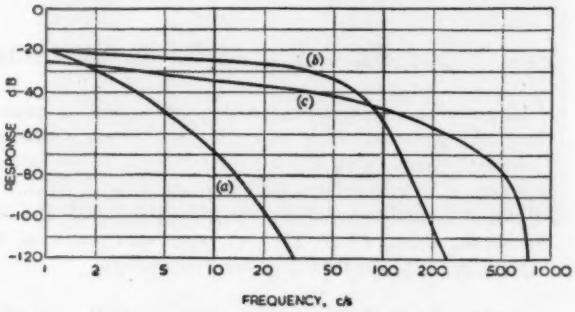
constant coefficients. It can also be used, together with a second slightly different cursor, to obtain the frequency response of a system from its transient response; or, in general, to obtain Fourier cosine or sine transforms.

Submarine Telegraph Signals

A digest of a Radio and Telecommunication Section paper (No. 1908) entitled "Signalling Systems for Submarine Telegraph Circuits," by C. J. Hughes, B.Sc., Associate Member. The full paper is published in November, 1955, in Part B of the Proceedings.

IN LONG-DISTANCE SUBMARINE TELEGRAPH CIRCUITS, the cost of the cable is usually much greater than the cost of the terminal apparatus. It follows that the use of complex terminal equipment is often justified if it leads to more efficient use of the cable.

Fig. 1 shows the frequency-response characteristics of



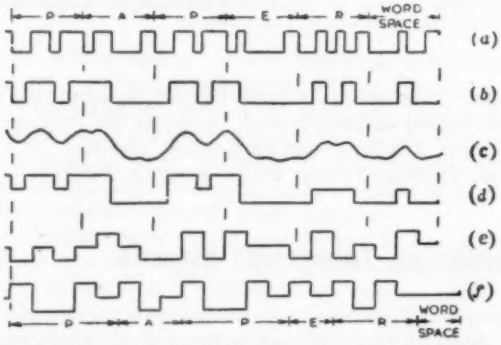
1 *Frequency-response characteristics of (a) unloaded, (b) continuously-loaded and (c) coil-loaded submarine cables*

The length in each case is of the order of 1 000 miles.

typical submarine cables. Since most cables in use to-day are of the unloaded type, the need for economy of band-width is apparent.

The rate of transmission of information over the cable is governed by the band-width and by the number of signalling conditions or voltage levels which may be applied to the cable. In general, any increase in the number of signalling conditions must be accompanied by a reduction in signalling speed if the same protection against noise is to be obtained. It may be shown that for some forms of noise, an overall increase in the rate of transmission of information is obtained if the number of signalling conditions is increased above the minimum of two.

The methods used to obtain an increased rate of transmission of information are illustrated in Fig. 2. If teleprinters are used, start and stop elements are signalled with each character to keep the receiving mechanism in step with the transmitter, as shown in Fig. 2(*a*). In a



2 *Specimen signals showing the different signalling systems and codes*

synchronous system, the start and stop elements are omitted in the signals transmitted over the cable as shown in Fig. 2(*b*). The signals shown in Figs. 2(*c*), 2(*d*) and 2(*e*) are typical of those produced in systems which employ three signalling conditions. These may be compared with the three-condition Morse signals shown in Fig. 2(*f*).

Non-linear Hard-Spring R.P.C. Systems

A digest of a Measurement and Control Section paper (No. 1728) entitled "The Response of Remote-Position-Control Systems with Hard-Spring Non-Linear Characteristics to Step Functions and Random Inputs," by J. C. West, B.Sc., Ph.D., Associate Member, and P. N. Nikiforuk, B.Sc., Ph.D. The full paper was published in September, 1955, in Part B of the Proceedings.

IN THE STUDY of linear control systems three main methods have been developed. Transient behaviour, i.e. the response to impulse, step or ramp input-functions, is a guide to the performance of the system for any other input and indicates speed of response and degree of damping. Many of the criterions of "goodness" are based on the step-function response.

The second method is the frequency-response analysis, the system being subjected to sinusoidal inputs at various specific frequencies. Here, band-width and magnitude of the resonant peak give indications of speed of response and degree of damping.

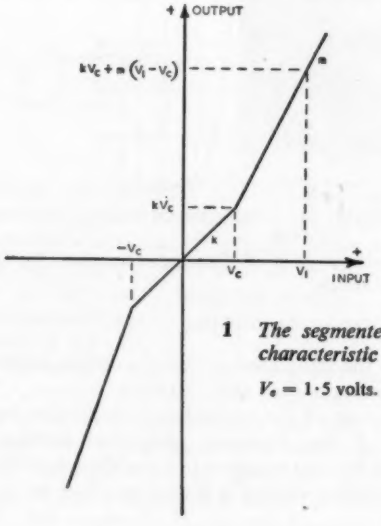
The third method is the statistical study of the performance for random inputs, and was developed so that the effect of noise signals or disturbances could be appreciated. It has also been stated that in practice a system will normally not be subjected to step or sinusoidal inputs and therefore the study of random input performance is more realistic.

In the linear analysis it is possible to relate the various methods so that only one is necessary to specify the complete performance. For the non-linear system with which the paper is concerned the relationships between the various methods of testing are unknown and furthermore would depend on the actual form of the non-linearity.

Thus it becomes of interest:

(*a*) To study one particular system with a non-linearity causing some distinctive feature in its behaviour.
(*b*) To compare the results of transient, frequency and random-input tests to see if any relationships exist similar to those for linear systems.
(*c*) To develop experimental and approximate theoretical analytical techniques for the study of these three methods.

For (*a*) the paper is concerned with what would be a simple second-order remote-position-control servo mechanism but for the non-linearity, and the authors consider the effect of a hard-spring non-linearity of the kind given in Fig. 1. They show that such a characteristic can actually decrease the response time without apparently affecting stability; Fig. 2 is a typical result.



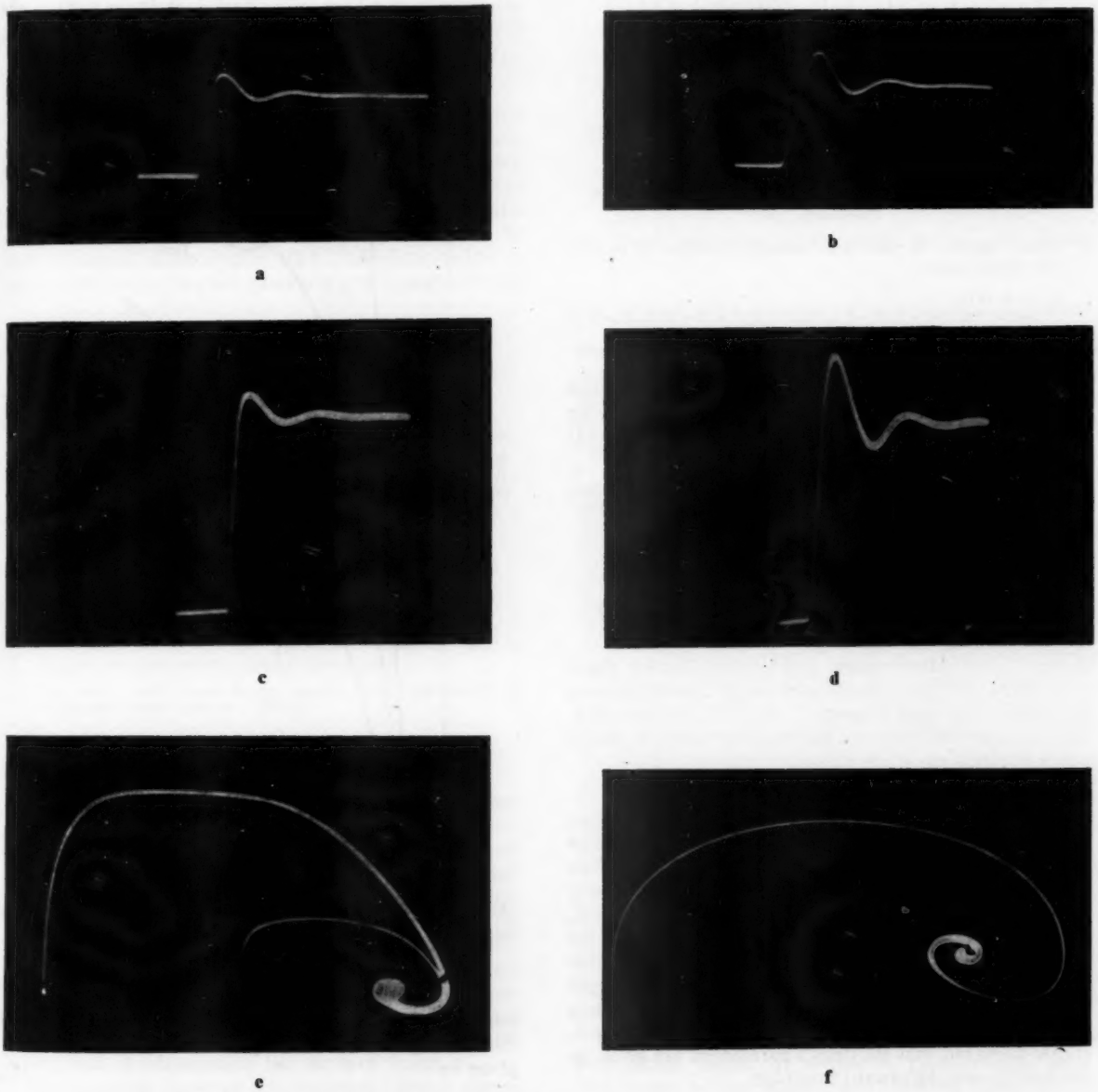
1 *The segmented-line non-linear characteristic*

$V_c = 1{\cdot}5$ volts. $k = 0{\cdot}94$.

In addition the step-response time is found to continue decreasing with increasing step amplitude. It is also worth noting that the tensioning of muscle in animals is now thought to follow a hard-spring relationship (approximately cubic) with the stimulating signal.

Under (*c*) the authors develop a phase-plane technique for obtaining the transient response and compare with experimental results. In addition the authors have ascertained experimentally the behaviour of the system to various forms of random inputs, and they discuss the methods of presenting the data. The effect of varying the signal power, for instance, is shown in Fig. 3 by portraying the error spectra for "white noise" input.

As regards the comparison of various test methods (*b*)

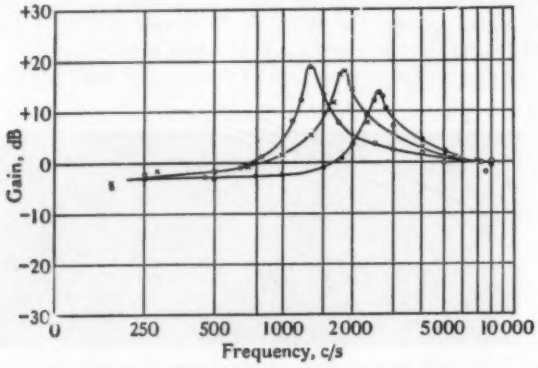


2 *Experimental transient responses and phase-plane trajectories*

$m = 5 \cdot 0$. D_e is critical in the non-linear régime.

(*a*) Non-linear response, $E_i = 4 \cdot 5$.
(*b*) Linear response corresponding to (*a*), $E_i = 4 \cdot 5$.
(*c*) Non-linear response, $E_i = 10 \cdot 4$.
(*d*) Linear response corresponding to (*c*), $E_i = 10 \cdot 4$.
(*e*) Non-linear trajectories.
(*f*) Linear trajectory corresponding to (*e*).

the paper is a sequel to another one,* in which the frequency-response analysis of the same system is given. The present work consists of the transient analysis and



3 *Error response to white noise showing the effect of varying the signal power*

$T_{d1} = 0{\cdot}16T_{d2}$
○ Linear response. × $M = 4{\cdot}1$, $N_{ti} = 0{\cdot}56$. • $M = 4{\cdot}1$, $N_{ti} = 2{\cdot}2$.

random-input performance and includes a comparison of all three results. It shows that there is a definite qualitative relationship which corresponds closely to that existing for the equivalent linear system.

* West, J. C., and Nikiforuk, P. N.: "The Behaviour of a Remote-Position-Control Servo Mechanism with Hard-Spring Non-Linear Characteristics," *Proceedings I.E.E.*, Paper No. 1621 M, March 1954 (101, Part II, p. 481).

Quick Response of Control Systems

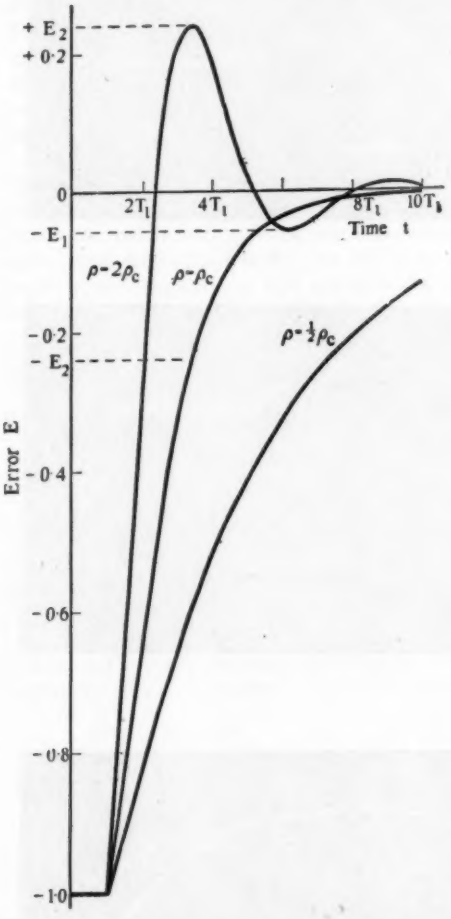
A digest of a Measurement and Control Section Paper (No. 1878) entitled "The Adjustment of Control Systems for Quick Transient Response," by A. T. Fuller, M.A. The full paper was published in September, 1955, in Part B of the Proceedings.

AN AUTOMATIC CONTROL SYSTEM will correct a given initial error in the controlled quantity, but will take time to do so. One of the main design problems is to reduce the time-lag to a minimum—a problem which usually involves formidable theoretical difficulties. However, simplification is possible if we adopt, as a measure of the time-lag, the time taken for the system to reach the state where the error is always within some very small fixed value. This settling time is minimized when the system response is adjusted to be, in effect, critically damped. It then turns out that the design parameters are given by reasonably straightforward formulae.

As an example, consider a closed-loop system comprising an integrator and a pure delay T_l in the forward path, and with full negative feedback from output to input. The response of the error, following a unit-step change of input, is illustrated in the diagram for three different adjustments of the integration rate ρ. One adjustment, $\rho = \rho_c$, corresponds to critical damping, and comparison of the graphs shows that this adjustment gives the quickest settling to small errors. The formula for ρ_c is simply

$$\rho_c = \frac{1}{\varepsilon T_l}$$

where ε is the base of natural logarithms. Also, the



Responses of the error, for three different adjustments of loop integration rate, to a unit-step input applied at $t = 0$

settling time is roughly proportional to a quantity called the settling-time-constant τ_s, which when minimized is given by

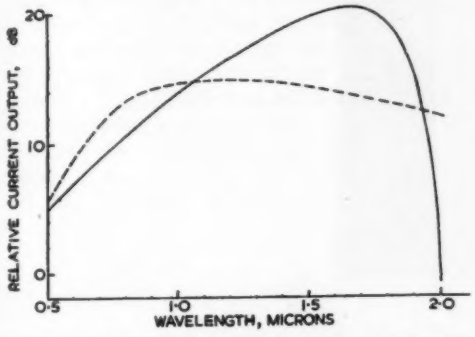
$$\tau_s = T_l$$

In view of this clarification of the theory, it is concluded that the optimum condition, which is termed *quasi-critical damping*, provides an appropriate design criterion of stability, at least for a large class of control systems.

A Germanium Diffused-Junction Photocell

A digest of a Radio and Telecommunication Section paper (No. 1860) entitled "A Germanium Diffused-Junction Photo-Electric Cell," by J. M. Waddell, M.A., Graduate, S. E. Mayer, Ph.D., and S. Kaye, B.Sc., Student. The full paper is published in November, 1955, in Part B of the Proceedings.

THE NEW GERMANIUM photo-electric cell described consists of a *p–n* junction which is biased in the reverse direction. When the cell is illuminated the reverse current increases. The junction itself is formed by the diffusion of a *p*-type impurity, gold, into *n*-type germanium. The noise component of the dark current in photocells made by this process is much smaller than that which occurs in similar cells made by other processes and a corresponding



1 *Spectral response of P50A photocell to incident light of uniform intensity plotted against wavelength*

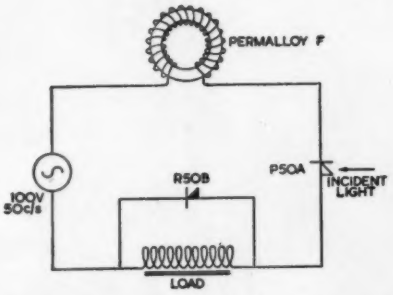
The dotted curve shows energy content versus wavelength for a tungsten-filament lamp at 2 700° K.

improvement in signal/noise ratio is obtained in applications involving low light levels.

The photocells respond to light of wavelength up to 2·0 microns (Fig. 1) and this makes the practical sensitivity very high when the cell is illuminated with light from a filament lamp which has its peak output in the near infra-red. The sharp cut-off at longer wavelengths would be expected to occur at the particular wavelength at which absorption of light by germanium drops sharply, but in these cells, unlike others which have been reported, it occurs at a slightly longer wavelength. No explanation of this anomaly has yet been found.

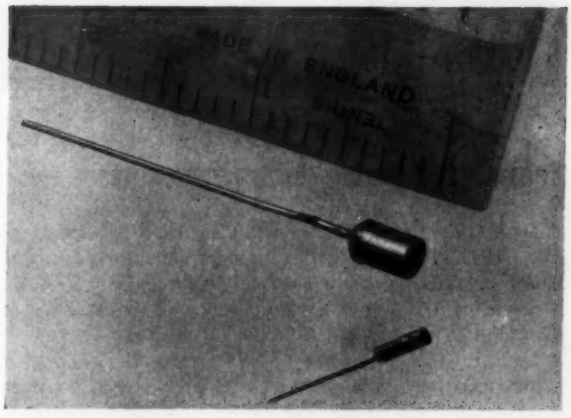
The frequency response and maximum power output are of the same order as for small junction transistors, approximately 300 kc/s and 100 mW. To obtain the latter power a load resistance of the order of 100 000 ohms is required, and since this is inconveniently high for relay coils a circuit has been developed (Fig. 2) which requires a load of approximately 1 000 ohms and gives a power output of approximately 1 watt.

The maximum power output of a junction photocell is partly determined by the maximum reverse voltage which may be applied to it. It can be shown theoretically



2 *Simple magnetic-amplifier circuit for use with junction photocell*

that the maximum reverse bias on the unilluminated cell is limited not only by working temperature but also by temperature rise; with germanium the maximum temperature rise is approximately 11° C. This result has been verified experimentally and emphasizes the need for



3 *P40A and P50A germanium junction photocells*

adequate cooling, since increased cooling will lead to increased working voltage.

Fig. 3 shows two photocells of this type. Both are hermetically sealed by means of metal-to-glass seals. The design of the larger one (P50A) is based on the requirement for adequate cooling of the germanium element, whilst the small one (P40A) has been designed for reading the holes in punched cards or teleprinter tapes, an application illustrated by the model shown in Fig. 4 (page 700).

A Germanium Diffused-Junction Photocell—*(contd.)*

4 *Six P40A photocells used for reading teleprinter tape*

Transistor Noise Measurements

A Digest of a Radio and Telecommunication Section paper (No. 1811) entitled "Measurements of Junction-Transistor Noise in the Frequency Range 7–50 kc/s," by W. L. Stephenson, B.Sc. The full paper is published in November, 1955, in Part B of the Proceedings.

A DETAILED INVESTIGATION of noise phenomena involves a statistical analysis of a very large number of measurements, but it is useful to know the approximate laws relating to the variation of noise with the operating conditions of amplifiers. This investigation was undertaken to determine the noise characteristics of junction transistors at frequencies above the audio range. The transistors measured were of the *p-n-p* fused-junction type with an α cut-off frequency of approximately 400 kc/s.

The method of measurement of the noise voltages was to use the superheterodyne principle, the mean level of the i.f. output being measured with a valve voltmeter. The equipment was sensitive to input levels of the order of 1 μV.

In expressing the noise characteristics of an amplifier, the noise factor is generally considered the most useful parameter since it is the ratio of the signal/noise ratios at the input and output. The noise factor, however, varies with the resistance of the signal source so that a more general approach to the problem is required.

In general, any 4-pole network which generates noise can be considered as an identical noiseless 4-pole network together with two noise generators situated at the input terminals. An analysis of such a network shows that there is a minimum value of noise factor with variation in source resistance, and, with a knowledge of the minimum noise factor and the optimum source resistance, it is possible to calculate the noise factor for any value of source resistance.

The most interesting conclusions to be drawn from the analysis of the measurements made are:

(*a*) The noise factor reaches a minimum of about 4 dB at about 25 kc/s as the frequency is increased, and rises beyond this point.

(*b*) The optimum source resistance is independent of frequency, and is not directly related to the input resistance.

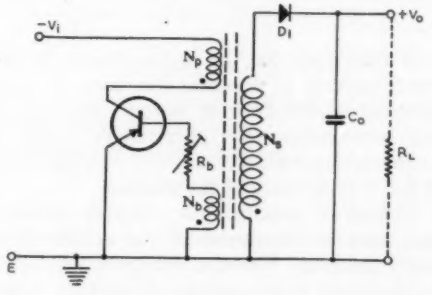
(*c*) The noise is completely independent of collector voltage.

Modern H.T. Supply Units

A digest of a Radio and Telecommunication Section paper (No. 1862) entitled "Transistor D.C. Convertors," by L. H. Light, B.Sc., and Mrs. Prudence M. Hooker, B.Sc. The full paper is published in November, 1955, in Part B of the Proceedings.

THE METHODS hitherto available for obtaining high and extra-high direct voltages from l.t. batteries, namely the vibrator power-pack and rotary convertor, both depend on mechanical devices and suffer from the disadvantages of short life and of requiring maintenance. Moreover, they are inefficient at low power levels and cause spark-generated interference. With the advent of the transistor, which can act as an efficient l.v. switching element, it is now possible to make all-electronic d.c. convertors working efficiently at power levels from a few milliwatts to several watts and with output voltages reaching several kilovolts. Output powers several times the transistor rating may be obtained. Such convertors are smaller and lighter than the mechanical convertors and are expected to be more reliable, but they suffer from the temperature limitations of the semi-conductor components. They fill the long-felt need for an efficient means of conversion at power levels of a fraction of a watt.

The paper describes the operation, design and applications of transistor d.c. convertors based on the circuit of Fig. 1. This is a transformer-coupled relaxation

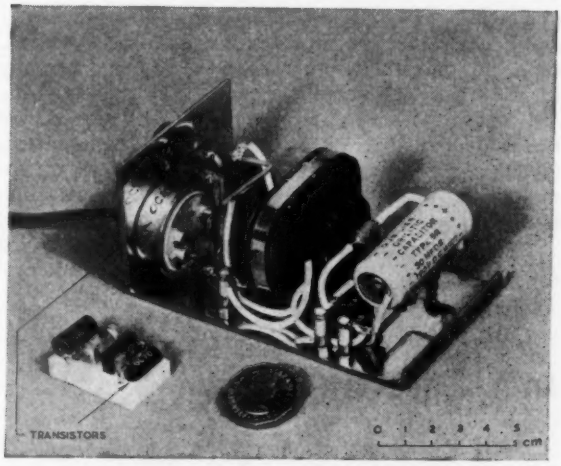


1 *A d.c. convertor circuit*

oscillator in which the transistor acts as a switch, periodically interrupting the current from the l.t. supply. Energy is stored in the inductance of the transformer during one part of the cycle and delivered to the output circuit at a higher voltage during the other part of the cycle.

The output power given by the circuit is approximately constant and independent of the load. A simple protection circuit using a gas-filled diode may be used to switch off the convertor if there is an excessive rise in output voltage due to load failure. A constant-voltage output characteristic may be produced by means of simple feedback-type stabilizing circuits, some of which are described.

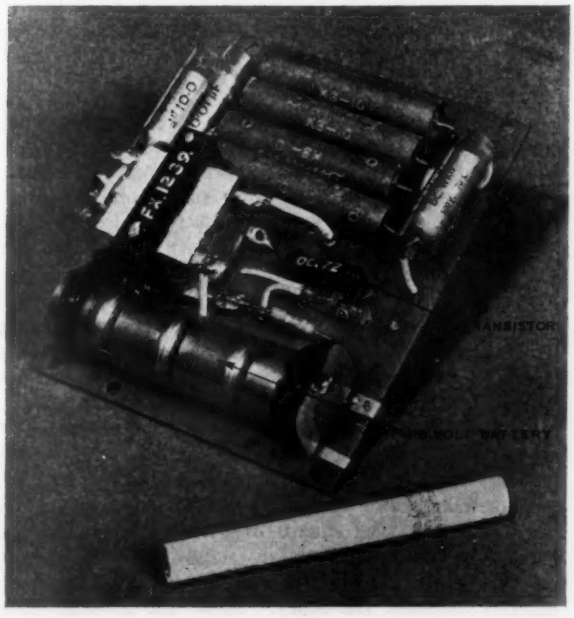
Fig. 2 shows two d.c. convertors; the miniature 2 mW unit gives h.t. supply at 30 volts for two hearing-



2 *2 mW and 4-watt convertor units*

aid pre-amplifier valves or one semi-electrometer valve, and the larger unit of 4 W, giving an output at 100–150 volts, is suitable for use with small portable transmitters and receivers.

3 *A 500-volt, 50 μA supply unit for a Geiger counter*



Voltage-multiplying circuits are used when very high output voltages are required. Fig. 3 shows a convertor providing 50 μA at 500 volts from the 4·8-volt battery mounted near the lower edge of the panel; it is suitable for use as the h.t. supply for a Geiger counter. A battery-operated oscillograph system has been made in which a single d.c. convertor provides the 2 kV 0·8 mA e.h.t. supply for the cathode-ray tube, and a 150-volt h.t. supply for the simple valve-amplifier circuit. This unit and the 4 W convertor shown in Fig. 2 use a single power transistor and operate from a 12-volt accumulator. Similar convertors can be used for e.h.t. supply for photo-multipliers, image convertors, etc., and for insulation testing.

The operating efficiency of most of the units described exceeds 70%.

An A.C. Network Analyser

A digest of a Supply Section paper (No. 1847) entitled "Dynamic Operation of an A.C. Network Analyser," by S. Kaneff, B.E., Graduate. The full paper was published in October, 1955, in Part A of the Proceedings.

THE PAPER DESCRIBES METHODS of synchronous-machine representation which permit the realization of a dynamic a.c. network analyser.

In an actual synchronous machine, the following relations are satisfied at every instant:

The power P_m supplied by the prime mover is equal to the sum of the electrical power output P_e and the power flow P_s being stored in, or taken from, machine rotors . . . . . (1)

The total energy stored in the rotors is proportional to the square of the instantaneous speed or frequency . . . . . (2)

These relations are satisfied in the basic synchronous machine representation illustrated in the functional diagram. A supply at frequency f_s provides power for the model network and acts as a reference. Adjustment of the phase of the output stage voltage (representing machine internal voltage) by the phase adjuster is one of the factors controlling power-flow conditions in the model power-system network (as in the actual case). A wattmeter measures the power flow P_e between machine model and network and this reading is compared with P_m, representing the prime mover power. Inequality produces a signal causing energy flow P_s to or from the energy store (representing energy stored in actual rotors), to make relation (1) hold good at all times. The measurement and comparison of P_m, P_e and P_s is performed by a three-element dynamometer-type wattmeter.

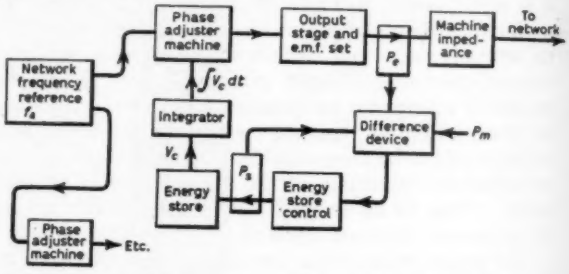
With a capacitor energy store, the stored energy is proportional to the square of the voltage across the capacitor, V_c, and in order to satisfy relation (2), this voltage is considered to be equivalent to the instantaneous machine frequency. Since the instantaneous frequency is equal to the rate of change of phase, the phase adjuster must be actuated such that

$$\text{Phase angle} \propto \int V_c\,dt$$

The integrator and phase-adjuster actions are produced by a single electromechanical unit.

Alternatively, by using the rotor of an electromechanical phase adjuster as the energy store, and appropriately metering P_s, no integrator unit is required, the phase adjuster being driven by the signal from the difference device.

For the study of power-system electromechanical oscillations, only changes in instantaneous frequency from the normal steady state are of interest, and, accordingly, only these changes are represented, the model being stationary for steady-state operation. The choice of time scale for the representation is arbitrary. The representation is accurate for wide departures in instantaneous frequency from normal, and can be used to study non-synchronous phenomena. Tests carried out in conjunction with a.c. network analyser units have proved the practicability of the method.



Basic phase-modulation system for synchronous-machine representation

The method of synchronous machine representation discussed may be employed in the construction of a completely dynamic network analyser (which can, if required, operate over a range of network frequencies from 50 c/s to 10 kc/s), or may be used in converting a normal a.c. network analyser to dynamic operation by change in generator units only.

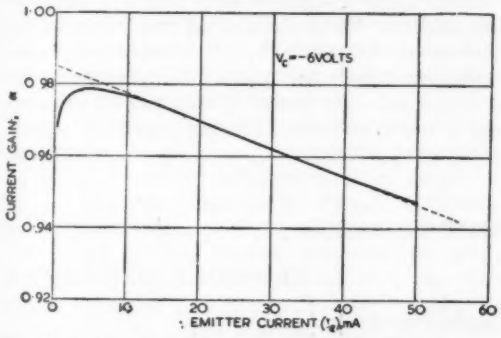
Transistor Power Amplifiers

A digest of a Radio and Telecommunication Section paper (No. 1861) entitled "Transistor Power Amplifiers," by R. A. Hilbourne, B.Sc., and D. D. Jones, M.Sc. The full paper was published in November, 1955, in Part B of the Proceedings.

UNTIL FAIRLY RECENTLY transistors were regarded as suitable mainly for applications requiring low output

powers. Over the past two years it has become clear that junction transistors can be designed to give large output powers, although these larger types are at present limited to operation in the audio-frequency range.

The power a transistor can control is ultimately limited by the temperature at the junctions of the device. Power dissipated in the transistor increases this temperature, and the increase depends on the method used for cooling. In practice there are other limitations, which may be more important than the cooling system. The collector supply voltage is generally limited to a few tens of volts because of the risk of electrical breakdown at the collector junction. This means that in order to obtain large output powers it is essential to operate the transistor up to high current levels. Although junction transistors in general have very linear characteristics, there is a serious departure from linearity when high currents are used, which is best shown by a curve of the small-signal current gain factor, α, (common-base arrangement) as a function of emitter current; this is given in Fig. 1. In

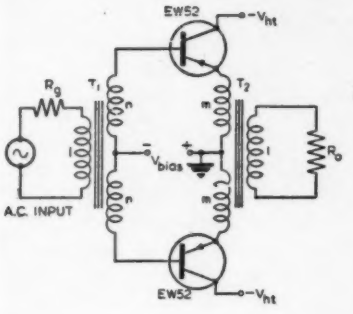


1 *Variation of current gain α with emitter current for a typical EW52 junction transistor*
The theoretical curve is shown dotted.

the common-emitter and common-collector arrangements the current gain factors become $\alpha/(1-\alpha)$ and $1/(1-\alpha)$ respectively. Since α is nearly equal to unity, variations in α produce large variations of these factors. These variations in current gain give rise to a flattening of the output waveform at high current levels and thus introduce harmonic distortion.

Any practical amplifier must withstand the no-signal condition. In a Class A output stage this means that, assuming the maximum efficiency of 50%, the maximum output power cannot exceed $P_{c(max)}/2$, where $P_{c(max)}$ is the maximum permissible collector dissipation. In a Class B amplifier, on the other hand, the dissipation under no-signal conditions is practically zero. Hence, assuming an efficiency as low as 67% (values nearer the theoretical maximum of 78·5% are obtainable in practice) an output of $2P_{c(max)}$ is obtainable. Thus, since $P_{c(max)}$ is generally a limiting factor with transistors, the Class B amplifier is more important than the Class A.

The paper discusses the performance of the common-base, common-emitter and common-collector Class B push-pull arrangements. The distortion arising from the variation of current gain with emitter current is discussed in detail and the gain of the three arrangements is calculated. It is found that the common-base arrangement introduces least distortion but has the lowest gain, whereas the common-emitter connection has the highest gain but also the most distortion, and it is concluded that the common-collector arrangement, as shown in Fig. 2,



2 *Basic circuit of the common-collector push-pull amplifier*

offers a good compromise between gain and distortion.

Another, and possibly in some applications a more important, form of distortion arises from the variation of the input resistance of the transistor at low values of emitter current. It is shown that it can be readily overcome and that the common-collector arrangement suffers least from this effect.

Methods of driving the common-collector amplifier, the significance of complementary arrangements of *n-p-n* and *p-n-p* transistors, and certain non-sinusoidal output circuits are among the aspects discussed. The high efficiency of junction transistors is particularly significant in non-sinusoidal output circuits, values of 90% and over being possible.

SYNOPSIS *of a Paper*

The following is a synopsis of a Radio and Telecommunication Section paper (No. 1925) entitled "An Introduction to Some Technical Factors affecting Point-to-Point Radiocommunication Systems," by F. J. M. Laver, B.Sc., Member, which is published in this month's issue of Part B of the Proceedings.

The paper briefly reviews some technical aspects of point-to-point radiocommunication systems, and serves as an introduction to the extensive literature on the subject. The contents of the paper include: the Transmission of Information; the Transmission of Signals, which covers noise and its effects, distortion (attenuation, phase, and non-linear), radio-wave propagation, and interference; General Processes, comprising modulation and demodulation, coding and multiplexing; and a Bibliography of 100 items.

HOME EVENTS

LONDON

MEASUREMENT AND CONTROL SECTION

The Annual Lecture to the Measurement and Control Section is always a notable event, and the lecture this year, given on the 3rd May, was no exception. On this occasion the lecturer was Professor W. V. Mayneord and he chose as his subject *The Medical Uses of Radioactive Isotopes*. He described techniques which have been used at the Royal Marsden Hospital for medical diagnosis and treatment.

The subject of the lecture was probably considered by many members to be rather outside their normal field of interest, and the attendance was not large. But those who heard the lecture realized at an early stage that electronic measuring techniques have many applications to the medical uses of radioactive isotopes.

Professor Mayneord introduced the subject by describing the production of radioactive materials by neutron bombardment in a nuclear reactor and said that the products of uranium fission were also a valuable source of certain radioactive isotopes. As an example of the former he mentioned the production of cobalt 60, now in wide use in connection with radiotherapy, and as examples of fission products used in medicine he quoted caesium 137, strontium 90 and xenon 133.

Professor Mayneord went on to describe some applications. One of the clinical applications is the use of sodium 24 to measure the circulation rate of blood. For this measurement a two-pronged probe, aptly called a "Winston" is used to measure time intervals as the radioactive tracer moves from one location to another in the patient. He also mentioned measuring a patient's total blood volume. For this purpose chromium 51 is used to label each blood cell in the sample. When this is mixed in the patient's circulation system, and a new blood sample taken, the total blood volume is calculable from the two specific activities.

The use of iodine 131 in thyroid treatment is well known, and Professor Mayneord described how iso-count-rate lines were determined on an actual patient by means of a scanning system, and how a similar system has been developed for locating brain tumours. A television type of scan and an Emitron storage method are used to plot the distribution of activity, after injection into the patient of a suitable radioactive chemical. The method depends for its success on the detection of count rates very close to the natural background rate. Examples were shown of strontium-loaded applicators for eye treatment. The instrument for determining isodose-rate lines was also exhibited; this uses a tiny scintillation counter, light guide and photo-multiplier tube, and measures the dose rate received by different parts of the eye.

Professor Mayneord next considered the uses of cobalt 60 and caesium 137. He mentioned that they are both suitable for industrial high-energy gamma-radiography as well as for therapy. He mentioned that shields were usually constructed of lead, tantalum-copper alloy, or when necessary, uranium, to collimate the gamma-ray beam. For diagnostic work it is sometimes possible to use gamma rays of low energy and then heavy shields are unnecessary. Convenient isotopes for this purpose are thulium 170 (produced by neutron bombardment in a nuclear reactor) and xenon 133 (obtained from fission products). Professor Mayneord showed radiographs of teeth taken with xenon held inside the mouth and using a one-second exposure. Many other applications were described, and the lecturer brought with him an array of exhibits and apparatus, which many in the audience stayed behind to inspect.

Proposing a vote of thanks, Mr. Bamford stated how glad he was that The Institution was keeping in touch with applied radioactivity and he thanked Professor Mayneord for showing members some of the good that has resulted from nuclear fission. Dr. Hartshorn seconding said that there was a good tradition that we should sometimes have a lecture to broaden our views. He thought that the present lecture was in that category. Nuclear fission had come in with a bang, but we had seen that night a broad picture of another aspect of nuclear fission and its applications.

D. T.

LOUGHBOROUGH

EAST MIDLAND CENTRE

A Successful Innovation

An informal reunion prior to the opening of the session was held at Loughborough on the 4th October, 1955. At the meeting there were 145 members, who were welcomed by Dr. Willis Jackson, Vice-President, Dr. J. H. Mitchell, the retiring Centre Chairman, and Mr. F. R. C. Roberts, the Chairman elect.

After a buffet tea, the Vice-President gave an informal talk on Institution activities and policy, and the fostering of the feeling of Corporate Membership. Mr. C. T. Rivington, Editor of the *Journal*, then gave a short discourse on matters concerning the form and scope of the *Journal*. A lively and interesting discussion followed covering many Institution topics, from non-specialist papers to Student membership; the Vice-President answered questions with support from Mr. Rivington. After concluding remarks by the Chairman, Dr. Mitchell, a vote of thanks to the speakers was proposed by Mr. Roberts. This was followed by the showing of the Institution film *The Inquiring Mind*, and a film *Highland Journey*, lent by courtesy of Bruce Peebles & Co.

The idea of holding an informal conversazione before the official opening of the session proved to be an outstanding success, as can be gauged from the numbers attending and the response in discussion to the addresses given.

W. A.

SCOTLAND

SCOTTISH CENTRE

The opening meetings of the Scottish Centre for the 1955–56 session took place in Edinburgh, Glasgow, Dundee and Aberdeen on October 4th, 5th, 6th and 7th respectively; on each occasion Mr. J. S. Hastie, the retiring Centre Chairman, introduced the new Chairman, Dr. E. Wilkinson of Aberdeen. In his introductory remarks Dr. Wilkinson spoke of the era of change that we are now entering in which the use of nuclear energy and the introduction of automation promises vast improvements in the standard of life throughout the world; he mentioned the opportunities that will be available to scientists and engineers of Great Britain, in fulfilling the need to export brain power in return for raw materials, and he referred to the valuable work of The Institution in maintaining educational standards for electrical engineers. Dr. Wilkinson, who had connections with the *Students' Quarterly Journal* in its early days, pointed out that the *S.Q.J.* had now reached its 100th issue and proposed that a congratulatory message be sent to Mr. J. H. Reyner, the Editor of the *S.Q.J.* throughout the whole of its life.

After the Centre meetings the three Sub-Centres held their inaugural meetings, the Chairman's Address to the North Scotland Sub-Centre being given both at Dundee and Aberdeen. In Edinburgh on October 4th the retiring Chairman of the South-East Scotland Sub-Centre, Mr. E. O. Taylor, presented to Mr. A. J. Oliphant the Sub-Centre Students' Prize for his paper on *The Transistor as a Circuit Element*. Mr. Taylor then presented to Mr. J. L. Egginton, until recently Honorary Secretary of the Sub-Centre, a copy of *The History of The Institution*; Mr. Egginton can justly be regarded as the chief architect of the Sub-Centre's success, since not only was he Secretary for its first three years but he was also Secretary of the interim committee that carried out the preliminary work leading to its foundation.

The new Chairman, Mr. W. B. Laing, then presented his Address on *The Electrical and Allied Industries in Scotland To-day*. Mr. Laing gave most valuable and interesting particulars of the work being carried out by the South of Scotland Electricity Board and the North of Scotland Hydro-Electric Board, but possibly the most fascinating part of his discourse dealt with the manufacturing industry; few of those present had previously realized the very wide range of electrical and allied products, ranging from 30 MVA hydro-electric generators and 120 MVA transformers to high-grade electronic equipment, that is made by over sixty firms situated in all parts of the country from Dumfries in the south to Inverness in the north. In proposing a vote of thanks to Mr. Laing for his outstanding survey, Mr. H. V. Henniker, Past-Chairman, mentioned that when he came to Scotland forty-two years ago there were only three electrical firms in the country, and he paid a tribute to Mr. Sam Mavor as the founder of the industry.

Photograph by courtesy of *Scottish Daily Record*

Dr. E. Wilkinson, Chairman of the Scottish Centre, watches Miss A. Gray put the first lady's signature in the Scottish Attendance Register

In Glasgow on October 5th Mr. J. Jardine was presented with an Institution Students' Premium for his Students' paper on *Servomechanisms*. Among the six new Associate Members welcomed on this occasion was Miss Agnes Gray, M.B.E., B.Sc., M.A., LL.D., the first lady member in Scotland to achieve Corporate Membership. Mr. R. J. Rennie, the retiring Chairman of the South-West Scotland Sub-Centre, then introduced the new Chairman, Mr. J. A. Aked. In his Chairman's Address Mr. Aked dealt, in his inimitable manner, with two points of detail concerning the operation of overhead transmission lines. The first was the design of a safe and effective portable earthing clamp; Mr. Aked described the many factors that had to be considered in ensuring that this apparently simple device would be perfectly safe in all circumstances and showed slides of short-circuit tests made to see that it would in fact handle any likely fault current that might occur should an earthed circuit inadvertently be made alive. The second part of the Address described an investigation now being undertaken on the corrosion of tower foundations; the collapse of a certain tower was found to be due to metal in the foundation having corroded away; similar corrosion on other towers, discovered by opening up the foundations, was illustrated by lantern slides; attempts are being made to correlate electrolytic potential readings with the degree of corrosion. In concluding his Address Mr. Aked acknowledged the assistance of his son, who is Chairman of the South-West Scotland Students' Section.

E. O. T.

NEWS *from Abroad*

ARGENTINA

ARGENTINA JOINT OVERSEA GROUP

The Committee of the Argentina Joint Oversea Group for 1955–56 is constituted as follows:

Chairman	B. G. Borissow, M.I.E.E., A.M.I.Mech.E.
Vice-Chairman	T. B. Glover, M.I.Mech.E.
Honorary Secretary and Treasurer	J. Combes, A.M.I.C.E., c/o Percy Grant and Co., Reconquista 314, Buenos Aires, Argentina.
Ordinary Members	H. Y. Buchanan, A.M.I.C.E. C. Mellor, A.M.I.C.E. R. M. Drysdale, A.M.I.Mech.E. H. M. Piette, A.M.I.Mech.E. F. H. G. Palmer, A.M.I.E.E. E. M. Whitaker, A.M.I.E.E.
Oversea Representative	A. C. Towers, M.I.E.E. (*ex officio*).

Intensive efforts are being made to revive this Joint Group, and the co-operation and support of all members of The Institution in Argentina is earnestly sought. Information about the Joint Group may be obtained from the Honorary Secretary, whose name and address are given above.

MIDDLE EAST

IRAQ AND PERSIAN GULF JOINT OVERSEA GROUP

A paper entitled *Progress and Problems of Electricity Supply in Baghdad* was read to members of the Iraq and Persian Gulf Joint Oversea Group by Mr. K. Kouyoumdjian, B.Sc.(Eng.), Mains Engineer of the Bagdad Light and Power Co., when the Group met in Baghdad on the 10th March, 1955. An abridged version of his paper is given below.

Prior to 1917 there was no public electricity supply in Baghdad, and it is not so long ago that lamp lighters went about the streets filling the street lanterns with imported kerosene.

The first power station was installed by the British army of occupation. It consisted of a steam plant with reciprocating engines brought over from India. The electricity generated was direct current at a potential of 440/220 volts for Baghdad proper, and alternating current at 3300 volts for the outlying districts, where it was stepped down and converted to direct current for distribution. Until 1922 the plant supplied lighting for the main roads used by the army and about 200 billets and camps. There were no civilian consumers except a few firms contracting for the army. Later, as billets were vacated, the local owners bought the electrical installation at a nominal price and were given a supply as a grace. Charges for the supply were made at a flat rate. In 1930 the peak load was just under 1000 kW and this was near the limit of the power station capacity. Although parts of this old equipment such as a number of motor convertors are giving good service even to-day, the plant as a whole was obsolete and inadequate.

The construction of a new power station was begun by the Bagdad Light and Power Co. in 1931. With continuous expansion the station to-day has an installed capacity of 41000 kW. Steam pressure is 400 lb/in^2 and temperature 770° F. There are eight boilers, four of the larger ones having a rating of 40 tons of steam per hour, and six turbo-alternator sets ranging from 2500 to 12500 kW. Electricity is generated at 11000 volts and controlled by air-blast switchgear. The town is supplied by a 33 kV transmission line, 11 kV feeders and distributors, and a 380/220 kV low-voltage network.

This expansion has not been without its problems, and owing to the rapid growth of the town, the introduction of industry, the change in the standard of living and the use of electrical equipment in the houses, these problems are even greater to-day. Some of them are special to Baghdad.

The river Tigris which runs through the town has its blessings and its caprices. Its annual rise and fall has a range of 30 ft. To ensure sufficient cooling water during the hot summer months and to resist the heavy floods of the spring the power station site and the type of water intake have had to be carefully selected. The river has an average width of 1350 ft, and several 11 kV cables have had to be laid in the river and over bridges to connect the two sections of the town. Inspection of the cables laid in the river is rendered difficult owing to heavy silting of the river bed. Seepage water is another problem for at certain times of the year it is only 2 ft below road level in places. Underground cables and joint boxes are surrounded with water and the soil around them is not stable.

The first 11 kV underground cable was laid in the streets of Baghdad in 1934. Within six months the cable started giving trouble through corrosion resulting from lack of drainage and from an inadequate sewage-disposal system. In 18 months the cable was in such bad condition that it had to be abandoned. Since then many miles of high- and low-voltage cables have been laid in various parts of the city, but the corrosive nature of the soil remains a problem.

On more than one occasion Baghdad has been an island surrounded by flood water, and the only route for a 33 kV transmission line to feed the southern end of the town from the power station in the north was along the eastern flood bund. The line had to be so designed that it would not affect the strength of the bund and that it would not in turn be affected by settlement of, or small breaches in, the bund. The pylons had to be erected on concrete foundations anchored on reinforced concrete piles.

Shortage of technical staff and skilled workers has always been a problem. Erection of plant has been carried out as far as possible by the staff that will maintain it. Very valuable service has been obtained from young men with little technical training but ability to learn and willingness to work.

While there has always been full co-operation between various services using the roads and pavements for under-

ground or overhead mains, there is considerable scope for co-ordination and planning so that pavements are not crowded with mains laid in a haphazard manner.

In the past little attention was paid by the consumer to the standard of installation in his premises, and the main requisite was low cost. Conditions, however, are changing rapidly and considerable attention is now being given to careful planning and sound installation.

VISITORS TO SAVOY PLACE

That there are members of The Institution throughout the world is well known, but some readers may not realize that so many of them manage to find their way to The Institution's headquarters; during the past few months members from the following countries have called at Savoy Place:

Australia, Belgium, Bermuda, Brazil, Canada, Ceylon, Cyprus, France, Gold Coast, Hong Kong, India, Jamaica, Jordan, Kenya, Lebanon, Malaya, Malta, Mauritius, Mexico, New Zealand, Nigeria, Nyasaland, Pakistan, Rhodesia, Sarawak, Sierra Leone, South Africa, Thailand, Trinidad, United States, Zanzibar.

These and other visitors have included Dr. Gabriel Kron from the United States, who is over here to give a special series of lectures at London University; Monsieur F. R. Félix, Président de Bureau International d'Électrothermie; Mr. J. E. Dion from Montreal, Canada; Mr. H. E. Cornish, Postmaster-General, Sarawak, and Mr. E. L. Spooner-Lillingston, Director-General of Telecommunications, Malaya.

Several of the Council's Oversea Representatives have also called on the Secretary: Mr. J. Houston Angus (West Africa); Mr. R. W. Bailey (Pakistan); Mr. A. G. Coates (Near East); Mr. D. S. Hill (Far East); Mr. J. M. Morris (Middle East); and Mr. F. Wade-Cooper (India).

"A Great Spirit of Co-operation"

The following note has been written by a member who has recently returned to this country after a two-year engagement in Australia.

By following a rather unorthodox itinerary I was able to spend some useful time in seven countries that I visited *en route*. The great hospitality I received from the engineers of all these countries has been an outstanding feature of my travels, and a few words of appreciation here may perhaps further this *esprit de corps* amongst engineers the world over.

Before leaving Australia for my indirect journey to England I spent a month in New Zealand, dividing my time between mountaineering and engineering. New Zealand is a beautiful country and offers a wide variety of scenic attractions from the great mountains of the Southern Alps, through the sunny beaches near all the main towns, to the thermal regions of the North Island. Some 90% of New Zealand's power is generated in the hydro-electric stations of the State Hydro Department, and thanks to its courtesy I was able to visit most of the larger schemes in both the North and the South Islands.

My route home was via Singapore, Malaya, Burma, India, Pakistan, Italy and France. In all these countries the engineer is leaving a decided mark, notably in the under-developed countries of the East. In Singapore and Malaya, for example, I visited modern power stations—contrasting incongruously with the abject poverty of the native dwellings close by. The engineers of such countries are playing a tremendously important part in their development.

Connaught Bridge power station, near Klang, Malaya

In France I was able to renew cordial relations with Électricité de France and spent a short time visiting some of the great hydro-electric schemes in the South of France, and finally the research and testing centre at Fontenay, near Paris.

In every country I visited I was received with the greatest kindness by the local engineers, who all went out of their way to make my stay as interesting as possible, and I feel most happy at having experienced a great spirit of co-operation. I had an extra "passport" in the form of a letter of introduction from the Secretary of The Institution, which proved most useful on arrival in each country.

D. W. S.

OVERSEA ATTENDANCE REGISTER

During the period 1st September to 30th September, 1955, the following members called at the Institution Building and signed the Attendance Register of Oversea Members:

ARCHER, R. A., M.A. (Lagos).
CIANTAR, L. C. (Vittoriosa, Malta).
DAWSON, R. J. (Mbale, Uganda).
DOS RAMOS, H. L. (Funchal, Madeira).
FLASHMAN, J. S., B.Sc. (Sydney).
GOLDING, J. W. (Nairobi).
HADFIELD, L. D., B.Sc., B.E. (Sydney).
JAYARATNE, M. W. F. (Ceylon).
KEITH, C. J., M.A. (Port of Spain, Trinidad).
LOW, S. L., M.A. (Singapore).
MAITRA, K. C. (Bombay).
MANSON, M. W. (Nairobi).
MARTIN, R. P. G. (Johannesburg).
MEHER-HOMJI, J. A. (Bombay).
MELLANBY, J., M.A. (Nigeria).
QUARTEY, E. L., B.Sc.(Eng.) (Accra).
TORRANCE, A. E. (Johannesburg).
WHITE, C. H. (Kuala Lumpur).
WILLIAMS, O. D. (Bulawayo).
WILSON, R. W., B.Sc.(Eng.) (Bangkok).
WUST, A. (Antwerp).

Journal I.E.E., November 1955

Problems Concerning the Distribution of Electricity in Australia

By **E. SANDS,** Associate Member, The Institution of Engineers, Australia

This article is based on a paper read before a Joint Meeting of The Institution and The Institution of Engineers, Australia. Mr. Sands is with the Department of Electricity, Brisbane City Council.

WHEN considering the supply of electricity for a developing community, there is a tendency simply to make provision for adequate generating capacity and to permit the distribution network to grow as best it may. It is only through a knowledge of the nature and geographical distribution of the load itself that the general pattern of an electrical distribution system can be determined. The planning of the other elements of the power system can then be co-ordinated.

The problem of designing a distribution system for the future may be divided into two sections:

(1) that of making adequate provision for the electrical load which is likely to be connected, and

(2) that of making this provision in the most economical manner possible.

The first involves an element of prophecy and the second is made difficult by the uncertainty of world economics. This article considers the problem as it applies to domestic consumers in Australia.

Help can be gained in the first part of the problem by observing trends and techniques in the United States, which in its technical development is a few years ahead of Australia, and where the circumstances are similar. A recent survey there revealed the types of new appliance which it is reasonable to expect will be in demand in Australia in the not-too-distant future. Five of these are television sets, air conditioners, clothes driers, dish washers and table cookers.

Tests taken in Chattanooga (United States) in areas having light, medium and heavy loads gave after-diversity maximum demands (a.d.m.d.) of 1·8 kVA, 2·3 kVA and 3·1 kVA respectively. It is significant that there was very little reduction in a.d.m.d. for numbers of consumers in excess of 10.

A recently-built working-class housing estate in Brisbane comprising 139 "all electric" houses was examined and found to have an a.d.m.d. of 1·5 kVA per consumer. When the occupants of these houses "settle in" and find the money for the purchase of additional appliances, it is expected that the a.d.m.d. will rise to 2·0 kVA per consumer. In better-class domestic areas the anticipated a.d.m.d. will rise to 3·5 kVA per consumer.

The second part of the problem deals with the most economical method of distributing electricity to the consumers and, once again, the techniques used in the United States are worthy of study. The most significant difference in that country is the almost universal adoption of low-rating distribution transformers. The most commonly-used ratings are between 15 and 25 kVA, but the present trend is to use larger transformers up to 75 kVA for urban areas. The l.v. distribution is a 220/110-volt, 3-wire single-phase system, and is taken into every all-electric house.

The points favouring the use of small pole-hanging 11 kV/240-volt single-phase transformers are as follows:

(1) A great number of small uniformly-sized transformers would be required and this would enable the manufacturer to set up a production line.

(2) Round transformer tanks are easily made in a drum-making machine.

(3) Factory and store handling is easier.

(4) Transformers can be overloaded to 150% as the value of the asset risked is small.

(5) When a transformer fails the number of consumers affected is small.

(6) L.V. radials are short and l.v. regulation is reduced.

(7) Neutral-voltage rises are lower owing to shorter neutrals.

(8) Additional loads in domestic areas can easily be catered for by the erection of additional transformers.

The following disadvantages may be considered:

(1) The initial cost per kilovolt-ampere of the smaller transformers is higher.

(2) Operating costs of the smaller transformers are higher.

(3) Full advantage is not taken of the load diversity.

Consideration of these points indicates that where overhead reticulation is used, the advantages of small transformers outweigh their disadvantages, and favour their use in Australia.

In order to make comparison between various possible methods of supply, the economics of the following six schemes applied to an estate were calculated.

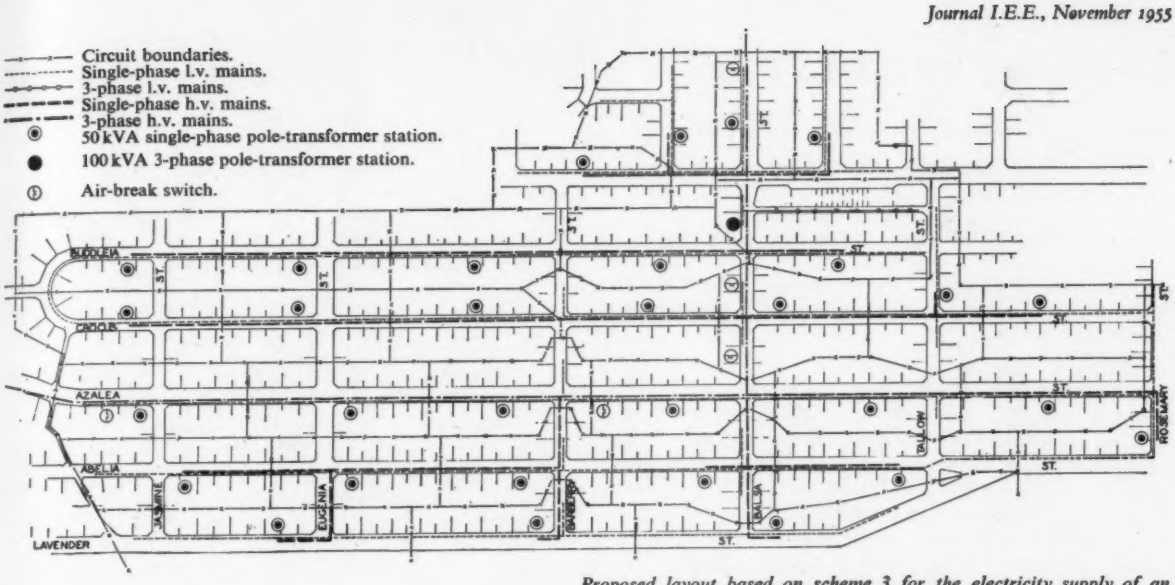
(1) 3-phase 415/240-volt l.v. distribution supplied from 300 kVA ground transformer stations, based on an a.d.m.d. of 2·0 kVA per consumer, and loading the transformer to 100%.

(2) 3-phase 415/240-volt l.v. distribution supplied from 300 kVA ground transformer stations, based on an a.d.m.d. of 3·5 kVA per consumer, and loading the transformer to 100%.

(3) Single-phase 240-volt l.v. distribution supplied from 50 kVA 11 kV/240-volt single-phase pole-mounted transformers based on an a.d.m.d. of 2·0 kVA per consumer, and loading the transformer to 100%. (See illustration.)

(4) Single-phase 240-volt l.v. distribution supplied from 30 kVA 11 kV/240-volt single-phase pole-mounted transformers, based on an a.d.m.d. of 2·0 kVA per consumer, and loading the transformer to 150%.

(5) Single-phase 240-volt l.v. distribution supplied from an 80 kVA 11 kV/240-volt single-phase pole-mounted transformer, based on an a.d.m.d. of 3·5 kVA per consumer, and loading the transformer to 100%.



Proposed layout based on scheme 3 for the electricity supply of an Australian housing estate, showing single-phase pole-transformer stations

(6) Single-phase 240-volt l.v. distribution supplied from a 60 kVA 11 kV/240-volt single-phase pole-mounted transformer, based on an a.d.m.d. of 3·5 kVA per consumer, and loading the transformer to 150%.

The results are shown in the Table, and from them it would appear that for an a.d.m.d. of 2·0 kVA per consumer the 50 kVA single-phase transformers are the most economical, while for an a.d.m.d. of 3·5 kVA per consumer in the same area the 80 kVA single-phase transformer is the most economical for both 40% and 50% load factor.

Experience shows that most domestic consumers in Brisbane are operating on a load factor above 40% on an annual basis. In view of this, and designing for an a.d.m.d. of 2·0 kVA per consumer and 40% load factor, 50 kVA single-phase transformers should be used. This means a saving of 13% on capital costs and 11% per consumer on annual charges. The initial costs for the single-phase system are always less than for 300 kVA 3-phase stations. The American overhead distribution system must be seriously considered where property frontages are large, and where the system must be kept flexible enough to provide for an increase in capacity without seriously upsetting the existing system.

Economics of Six Electricity Supply Schemes (Costs quoted are in Australian currency)

	Scheme (1): 300 kVA transformer loaded 100%				Scheme (2): 300 kVA transformer loaded 100%			
	40% load factor		30% load factor		40% load factor		50% load factor	
	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer
	£	£ s. d.	£	£ s. d.	£	£ s. d.	£	£ s. d.
Initial capital cost	33 485	55 16 0	33 485	55 16 0	39 930	66 11 0	39 930	66 11 0
Virtual cost ..	76 405	127 7 0	73 930	123 4 0	114 273	190 10 0	119 208	198 14 0
Annual charges	3 394	5 13 3	3 316	5 10 6	4 769	7 19 0	4 923	8 4 0

	Scheme (3): 50 kVA transformer loaded 100%				Scheme (4): 30 kVA transformer loaded 150%			
	40% load factor		30% load factor		40% load factor		30% load factor	
	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer
	£	£ s. d.	£	£ s. d.	£	£ s. d.	£	£ s. d.
Initial capital cost	26 095	43 10 0	26 095	43 10 0	24 979	41 12 0	24 979	41 12 0
Virtual cost ..	72 651	121 2 0	70 593	117 13 0	75 721	126 4 0	73 096	121 16 0
Annual charges	3 052	5 1 9	2 989	4 9 6	3 114	5 3 9	3 034	5 1 3

	Scheme (5): 80 kVA transformer loaded 100%				Scheme (6): 60 kVA transformer loaded 150%			
	40% load factor		50% load factor		40% load factor		50% load factor	
	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer	Total cost	Cost per consumer
	£	£ s. d.	£	£ s. d.	£	£ s. d.	£	£ s. d.
Initial capital cost	28 159	46 18 0	28 159	46 18 0	27 105	45 3 0	27 105	45 3 0
Virtual cost ..	98 496	164 3 0	102 381	170 13 0	108 814	181 7 0	117 172	195 6 0
Annual charges	3 921	6 10 9	4 043	6 14 9	4 210	7 0 3	4 473	7 9 0

CORRESPONDENCE

THE THEORY OF DIMENSIONS*

From LAURENCE H. A. CARR, M.Sc.TECH., *Member*

It does not appear to be generally appreciated that the value of the Theory of Dimensions can be considerably increased if the directional properties of the dimension of length are taken into account.

This can most readily be done by the use of the subscripts x, y and z, corresponding to the three directions in space; the use of a subscript is continued where the resulting dimension corresponds to a vectorial, and not a scalar, quantity.

With the above convention, the dimensions of torque are no longer identical with the dimensions of work.

By employing the standard symbols laid down in B.S. 1991, the dimensional equations for force, work and torque become

$$[F_x] = [ML_xT^{-2}]$$
$$[W] = [F_xL_x] = [ML_x^2T^{-2}]$$
$$[T_z] = [F_xL_y] = [ML_xL_yT^{-2}]$$

Further an angle now has dimensions:

$$[\theta] \text{ or better } [\theta_z] = [L_xL_y^{-1}]$$

from which, as before,

$$[W] = [T_z\theta_z] = [ML_x^2T^{-2}]$$

The above extension of the Theory of Dimensions is not claimed to be new, but it is not so widely used as its merit deserves.

* This letter was received before the publication of the letter from Mr. L. Young on page 652 of the October *Journal*.—*Editor*.

Mr. Carr was formerly with the Metropolitan-Vickers Electrical Co., and is now a consultant.

A NEW IMPEDANCE BRIDGE

From W. F. LOVERING, B.Sc., M.Sc., *Associate Member*

This letter briefly describes a new bridge which has been devised for the measurement of the impedance parameters of 3-terminal networks, passive or active, including transistors. It is based upon the use of inductively coupled ratio arms to measure the impedance parameters specified by

$$V_1 = I_1Z_{11} + I_2Z_{12}$$
$$V_2 = I_2Z_{22} + I_1Z_{21}$$

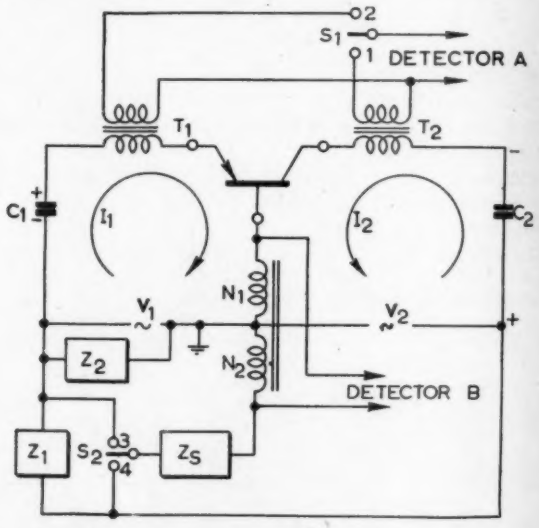
A simplified circuit illustrating the principle is shown in Fig. 1. V_2 is a fixed source of voltage and V_1 is the potential difference developed across Z_2. If switch S_1 is closed to position 1 and V_1 is adjusted in phase and magnitude, by adjustment of Z_1, so that detector A indicates zero signal, then I_2 is zero when

$$V_1 = I_1Z_{11} \text{ and } V_2 = I_1Z_{21}$$

If switch S_2 is now closed to position 3 and Z_S is adjusted for zero signal in detector B, the total ampere-turns in the ratio arm are zero when $N_1I_1 = N_2V_1/Z_S$, i.e. when $Z_S = Z_{11}N_2/N_1$. With S_2 closed to position 4 and Z_S adjusted for balance $N_1I_1 = N_2V_2/Z_S$ or $Z_S = Z_{21}N_2/N_1$.

With S_1 closed to position 2 and V_1 adjusted for zero signal in detector A, I_1 is zero, and V_1/I_2 ($= Z_{12}$) and V_2/I_2 ($= Z_{22}$) may be measured.

The impedance of the primary of the transformer (T_1 or T_2) used to indicate zero current and the reactance of the capacitor are in series with Z_{11} and Z_{22} respectively, and should therefore be small; in practice an inductance



1 *Circuit for measuring transistor parameters*

of 1 mH and a capacitance of 20 μF may be used, with a total impedance of less than 2 ohms between 1 000 and 2 000 c/s. With a more complicated circuit it is possible to arrange that the impedance added to Z_{11} or Z_{22} is a pure resistance over a wide frequency range; a compensating resistor may then be added in series with Z_S.

If the ratio arm is well designed its leakage reactance and resistance can be kept to a fraction of an ohm so that when Z_S has the correct value the impedance added to Z_{12} or Z_{21} is negligible. However, in the preliminary

Mr. Lovering is in the School of Electrical Engineering, New South Wales University of Technology, Sydney.

adjustment to make I_1 or I_2 zero, Z_S is, in general, not set at the correct value, and a finite impedance is added to Z_{12} or Z_{21}. To obviate the necessity of repeated readjustment a switch is connected across the ratio arm N_1 and is short-circuited whilst V_1 is being adjusted.

Z_2 is made small (about 1 ohm) so that switching from position 4 to position 3 does not necessitate a readjustment of Z_1.

The transformers T_1 and T_2 present the major difficulty in design, since the secondary e.m.f. is only a few microvolts whilst a p.d. of 2–3 volts may exist between primary and secondary. A screened and balanced design has been evolved in which the effects of capacitance currents in the windings may be completely balanced.

Preliminary experiments suggest that the parameters of any transistor may be determined with an error of less than 1%. To avoid instability with some point-contact transistors a resistor R may be added in the emitter lead such that $(R + r_e) > (\alpha - 1)\, r_b$, and a compensating resistor added in series with Z_S (r_e = emitter resistance; r_b = base resistance; α = current amplification.)

OBITUARY

GEOFFREY FERDINAND FALK

Geoffrey Ferdinand Falk died suddenly on the 24th May, 1955, at the age of 56.

Mr. Falk was educated at University College School, London, at Repton and at Faraday House. During the First World War he joined the Wiltshire Regiment and was commissioned in 1918. After the war he served for a short time in the Territorial Army in the Manchester Regiment, and in 1920–21 he received a year's practical training with the General Electric Co. He became apprenticed to Falk, Stadelmann and Co. in 1921 and three years later he was appointed Chief Assistant in the Birmingham Branch. In 1927 he became Assistant Manager at the Cardiff Branch and subsequently was in the Head Office as Manager of the Domestic Appliances Department. In that capacity he was instrumental in developing a wide range of electrical appliances, including cookers.

On the outbreak of the Second World War he joined the 2nd London Divisional Signals, attaining the rank of Lieutenant-Colonel and becoming Chief Signal Officer, South Eastern Command. He also served with the British Army of the Rhine.

He was appointed a Local Director of Falk, Stadelmann and Co. in September, 1943, and joined the Board in January, 1947. His responsibilities then extended over a group of factories and departments manufacturing and distributing a wide range of electrical products. In addition, he carried with great distinction the duties of First Assistant to the Managing Director. He was a well-known figure among members of B.E.A.M.A., particularly those in the sections of the Association concerned with domestic appliances, switchgear and accessories. His loss will be greatly felt by his many friends in the electrical supply industry and distributive trades.

He joined The Institution as a Graduate in 1929 and was elected an Associate Member in 1931 and a Member in 1943.

W. M. F. T.

WILLIAM GILBERT

William Gilbert, who died on the 2nd June, 1955, after a short illness, was born on the 29th July, 1892.

He was educated privately and at Roborough School, Eastbourne. He received his technical training at the Northampton Institute, London, from 1908 to 1912. At the age of 20 he joined the electrical engineering firm of T. Harding Churton and Co., of Leeds, and became Assistant Manager. During the First World War he served with the 15th (Leeds City) Battalion of the West Yorkshire Regiment, and with the Royal Flying Corps.

In 1919 Mr. Gilbert joined the Sunderland Forge and Engineering Co. as Second Designer and stayed with that company until 1924, when he was appointed Chief Electrical Engineer at Ransomes, Sims and Jefferies, of Ipswich, a position he held until his death. In this capacity during his 30 years with the company, his responsibilities embraced those of Works Electrical Engineer and Chief of Electrical Designs of all the company's products, including a.c. and d.c. motors and control gear for battery vehicles, trucks and trolley-buses.

Mr. Gilbert travelled widely for this company and represented them at many trolley-bus conventions in Europe; he was well known among the transport organizations. Several patents taken out by the company for control schemes originated from him.

He was an active and keenly interested member of the Eastern Electricity Consultative Council and, only a few weeks before his death, was appointed Deputy Chairman of the Council by the Minister of Fuel and Power.

A widely read man, a sportsman and a musician, William Gilbert was of a modest and lovable disposition. He will long be remembered with respect by his many colleagues for his consistently unruffled and conscientious nature which, at all times, was imbued with a keen and kindly sense of humour. He is survived by his widow. He joined The Institution as a Student in 1912 and was elected an Associate Member in 1917 and a Member in 1930.

C. A. M.

RONALD GRIERSON

Ronald Grierson, who died on the 5th June, 1955, was born on the 7th May, 1886, at Walsall, Staffordshire. He was educated privately before going to the University of Birmingham in 1903.

Between 1906 and 1910 he gained experience in the electricity supply industry at Mansfield, Rochdale and Poplar, and in 1910 he was appointed Chief Engineer to Provincial Cinematograph Theatres, Ltd., to whom he was responsible for the design, installation, operation and maintenance of the entire electrical and mechanical equipment of their 25 theatres and film studio.

During the 1914–18 war he saw service in Egypt, Gallipoli and France with the Royal Marines and Royal Engineers in both Field and E. and M. Companies, and was mentioned in Sir Charles Munroe's dispatches during the Gallipoli campaign.

From 1922–36 he was Managing Director of Grierson, Ltd., and during that time carried out major electrical installations for such places as the new bullion vaults of the Bank of England, the new City Hall at Sheffield, and the new municipal buildings at Peterborough, Kingston-on-Thames and Southampton. He was also responsible for installation work at King's College, Cambridge, the Richmond Ice Rink, Devonshire House, and a number of West End theatres, clubs and shops.

Mr. Grierson was particularly interested in electrical thermal-storage installations and was associated with a large number of schemes, including the Bankside control room for the Central Electricity Board, the West London Synagogue, the Mersey Tunnel and its control offices, the St. Pancras Town Hall and the National Sporting Club.

In 1936 he joined the Northmet Power Co. as Heating Engineer and continued in that capacity for the company, and later for the Eastern Electricity Board, until his retirement in December, 1951.

Mr. Grierson was a past member of the Council of The Institution of Heating and Ventilating Engineers, who awarded him their Silver Medal and Institution Premium for papers which he read. He was also a member of The Institution of Mechanical Engineers and the author of several books.

Mr. Grierson joined The Institution as a Student in 1907 and was elected an Associate Member in 1911 and a Member in 1932. He was a Member of Council from 1925 to 1927, from 1930 to 1933, and again (*ex officio*) in 1942–43, when he was the Chairman of the Installations Section. He also served The Institution as Chairman of several sub-committees and as a member of the Wiring Regulations and Advisory Sub-Committees, besides representing The Institution on British Standards Institution and other technical committees.

For papers presented before The Institution he was awarded the Ayrton Premium in 1931 and 1935 (jointly), the Crompton Premium in 1946 (jointly) and the Installations Section Premium in 1942.

In his own words, his life "has all been good fun."

L. S.

THOMAS EMLYN HARRIS

Thomas Emlyn Harris, C.B., C.B.E., who died on the 18th July, 1955, was born at Aberbeeg, Monmouthshire, on the 31st May, 1894, and was educated at Abertillery. He was apprenticed to Partridge, Jones and Co., colliery proprietors, of Llanhilleth, and in 1912 became a Junior Assistant in the Abertillery electricity undertaking. Three years later he attended an electrical engineering course at the University College of South Wales, Cardiff, but this was interrupted by national service and it was not until 1921 that he obtained his diploma.

In 1917 he joined the Ebbw Vale Steel Iron and Coal Co. as Electrical Assistant and was engaged in the installation and maintenance of substation and heavy electrical plant. From 1921 to 1924 he was employed by the Metropolitan-Vickers Electrical Co., at Manchester, as Assistant Engineer and was engaged on erection and testing and on the running of official tests on generating plant. In the latter year he was appointed Shop Manager at the Royal Ordnance Factories, Woolwich, where he was in charge of the generation and distribution of electricity and was responsible for the maintenance of electric motors with a total rating of some 20 000 h.p.

Subsequently he was Shop Manager and Superintendent of the Royal Ordnance Factory at Blackburn, and was then transferred to London as Assistant Director of Ordnance Factories. During the period 1939–1945 he was actively employed in the planning and building of many new ordnance factories. He was later promoted to Deputy Director, Director and Deputy Director-General. He had accepted a position with the Atomic Energy Authority, which he was occupying at the time of his death. Mr. Harris was made a C.B.E. in 1946 and C.B. in 1951.

He joined The Institution as an Associate Member in 1925 and was elected a Member in 1932. He was also a member of The Institution of Mechanical Engineers.

H. W. H.

EDWARD ERNEST HOADLEY

Edward Ernest Hoadley, C.B.E., who died on the 8th July, 1955, was born at Rochester, Kent, on the 24th October, 1874, and educated at Sir Joseph Williamson's Mathematical School, Rochester.

He entered the electricity supply industry at the age of 16, when he was articled to the Chief Engineer of the Rochester and Chatham Electricity Supply Co., and two years later he went to Finsbury Technical College to complete his education. He was successful in obtaining a City and Guilds Diploma, and was awarded the Salomons Scholarship by The Institution in 1894.

After holding junior appointments with the Eastbourne Electricity Supply Co., and Islington Corporation, he went to Worcester as Chief Assistant to Worcester Corporation at the age of 23. Later he accepted the position of Resident Engineer at the power station at

Barking, and then in 1899 he returned to Worcester as Chief Engineer and Manager of the Electricity Department, being one of the youngest men to hold such a position. From Worcester he went to Maidstone in 1901 as the Borough Electrical Engineer to the new Electricity Department of the Maidstone Corporation and remained there for the remainder of his career, except for a period during the 1914–18 war when he held a commission in the Royal Army Service Corps. Whilst his chief interest lay in the extending of electricity supply, in which cause he was responsible for the design and construction of many power stations, his activities covered a wider field, and he served on many national committees. He held the office of Honorary Secretary of the Incorporated Municipal Electrical Association until, in 1935, he was elected President. During his year as President of the I.M.E.A. the first and only combined National Electricity Supply Convention was held, when company undertakings combined with municipalities, and he was elected the President of this Convention.

During the Second World War he served on several national committees, one of which was the National Consultative Committee set up by Major Gwilym Lloyd-George. From 1942 to 1944 he was Chairman of the British Electrical Development Association and President of the Electrical Industries Benevolent Association.

He was made a C.B.E. in 1946. From 1947 until his retirement in 1949 he was District Manager of the South Eastern Electricity Board at Maidstone.

Mr. Hoadley joined The Institution as a Student in 1894 and was elected an Associate in 1896, an Associate Member in 1900 and a Member in 1902. A memorial service was held in the Queen's Chapel of the Savoy, London, on the 27th July, 1955, under arrangements made by The Institution in conjunction with other organizations in the electrical industry. H. F. K.

THOMAS ARCHIBALD KERR

Thomas Archibald Kerr, who died on the 26th April, 1955, at Buxton, was born near Glasgow on the 7th January, 1874. He was educated at Bootle College, and at the Central Technical College, South Kensington.

He served his apprenticeship as a marine engineer, but did not pursue that career—instead he studied at South Kensington and obtained his A.C.G.I. This was followed by six years of works experience with Siemens Brothers and the Walker Wallsend Union Gas Co., after which he was appointed as a Shift Engineer at the Corporation Electricity Works, Paisley. Some time later he transferred to a similar post at the Stuart Street station of the Manchester Corporation.

In 1908 he succeeded Mr. J. M. C. McGregor as Engineer and Manager to the Trafford Power and Light Supply Co., which owned and operated the Trafford Park station and supplied electricity in the newly created industrial area of Trafford Park, Manchester. When the Stretford Urban District Council purchased the company's undertaking in 1919, Mr. Kerr was appointed Chief Engineer to the Council's Electricity Department, and on the formation in 1928 of the Stretford and District Electricity Board he became the Board's first Chief Engineer, a position which he held until his retirement in 1940. It is interesting to recall that in 1908 the Trafford Park station contained d.c. plant with a capacity of 4000 kW to meet a maximum demand of 2560 kW; in 1940 the Stretford Board sold nearly 200 million kWh with a maximum demand of nearly 50 MW.

In the first year after Mr. Kerr's appointment to Trafford, the first a.c. supplies at 6600 volts, 50 c/s, were given, by means of inverted rotary convertors. In the early years at Trafford he was engaged on experiments in pulverized-fuel firing, and he also installed pneumatic suction plant for unloading coal from barges.

Mr. Kerr was a typical dour Scot who kept himself to himself. He was rather terse and abrupt in his manner and a strict disciplinarian, but he was kindly almost to softness when his sympathies were aroused. He was fiercely honest, keen on efficiency and operating costs, and had no time for slackers, wasters or window-dressing of any kind. Whilst he was difficult to get on with and rather remote from his employees as a whole, those in closest contact with him felt a real affection for him. He leaves one son and two daughters.

He joined The Institution as a Student in 1896 and was elected an Associate in 1898, an Associate Member in 1899 and a Member in 1918. He served on the North-Western Centre Committee from 1928 to 1931. H. G. B.

HAROLD LISTER KIRKE

Harold Lister Kirke, C.B.E., who died on the 25th August, 1955, after a long illness which had incapacitated him for several years, was born on the 7th January, 1895. Few people other than those associated with the technical development of broadcasting will be aware of the outstanding importance of his work in that field during a period of more than twenty-five years.

He was an engineer by birth rather than by training—in fact he began his career in a business which was not concerned in any way with science or engineering. However, when the First World War came he very soon enlisted in the Army, and shortly afterwards received a commission in the Royal Fusiliers, where his natural aptitude for technical matters led to his becoming a battalion signal officer. Success in this capacity eventually resulted in his being seconded to the Signals Branch of the Royal Engineers. At this time wireless telegraphy, and even telephony, was being developed as rapidly as possible for military purposes, and after attending Army courses he became a specialist wireless officer and, for a short time after the war, Chief Instructor at the Army wireless depot at Fenny Stratford.

It was on this background that his highly successful civilian career was based. He worked untiringly to catch up with his lack of early technical training, and to equip himself for a responsible engineering post in civil life.

In 1920 he received an appointment from Marconi's

Wireless Telegraph Co. as an experimental designer, and he immediately began to show great aptitude and originality. In 1924 he was engaged by the recently-established B.B.C. to form the nucleus of a research department which he headed with outstanding success for many years. He always enjoyed the whole-hearted respect and loyalty of his staff, in spite of the fact that the majority possessed academic qualifications which he had never had the opportunity to gain. He was appointed Assistant Chief Engineer in 1950.

He was much concerned personally with the extensive building-up of B.B.C. engineering equipment during the expansion of transmitting power during the war itself. He also played an important part in the experiments on television and the establishment of a regular service in 1936, and again in its hurried re-establishment after the war.

He was especially interested in the possibilities of v.h.f. broadcasting as applied to the B.B.C. services, and he directed the long series of experiments which first led to the building of the Wrotham station, and eventually to the opening this year of the v.h.f. sound service.

Perhaps because of his early experience, Mr. Kirke never lost sight of practical requirements, but at the same time he always kept in mind the more theoretical aspects of the problems he was trying to solve. He had an almost uncanny genius for the diagnosis of abstruse technical difficulties and failures which had baffled others. In 1947 he was made a C.B.E. for his services to broadcasting.

His sudden illness came many years before the normal end of his active career. Had this not happened, there is no doubt that he would have added a great deal more to his outstanding contribution to broadcasting.

He joined The Institution as an Associate Member in 1935 and was elected a Member in 1939. He wrote several Institution papers, and in 1929 in joint authorship with P. P. Eckersley and T. L. Eckersley he contributed a paper to the *Journal* entitled "The Design of Transmitting Aerials for Broadcasting Stations," and in 1936 with A. B. Howe, another paper entitled "The Acoustical Design of Broadcasting Studios," for which the authors were awarded the Duddell Premium. He served on the Wireless Section Committee from 1937 to 1940 and again in 1943–44, and was Chairman of this Committee in 1942–43. He was again Chairman of the Committee (of the now renamed Radio Section) in 1944–45. From 1947 to 1950 he served as an Ordinary Member of Council and as a member of the Papers Committee. During this period and until 1951 he also served on the Research Committee.

He was also the Vice-President of the Institute of Radio Engineers in 1952. N. A.

THOMAS LAWRIE

Thomas Lawrie, C.B.E., who died suddenly on the 13th August, 1955, was born on the 8th March, 1901. His death has deprived Scotland of a most distinguished engineer who had devoted most of his life to Scottish hydro-electric development.

Mr. Lawrie was born at Laurencekirk, Kincardineshire, and was educated at Mackie Academy, Stonehaven, at Leighton Park School, Reading, and at King's College, Cambridge, where he took the Mechanical Sciences Tripos and gained his B.A. degree, leading to an M.A. degree in 1927. His apprenticeship began in 1923 at the English Electric Company's Stafford Works, though he also received training both in the United States and at Dundee. For three years he worked in the Hydro-Electric Section of the English Electric Co., before becoming, in 1928, Engineer and Secretary of the Power and Traction Finance Co. In this capacity he was concerned both with work oversea and with the promotion of the Galloway water power scheme. From 1931 to 1940 he was Secretary of the Galloway Water Power Co.

Fond of the sea and of sailing, he was a Lieutenant-Commander, R.N.V.R., during the Second World War and served at Dunkirk and Dieppe.

With the formation of the North of Scotland Hydro-Electric Board in 1943 it became essential to make use of Mr. Lawrie's outstanding knowledge and experience, and so he was released from the Navy in that year to become Secretary of the Board. In this capacity and, from 1948 onwards, in the capacity of General Manager, he played—as he had for the Galloway scheme in South Scotland—a major part in the successful development both of the water-power resources of Northern Scotland and the making available of electricity supply.

Latterly he had become deeply interested in the possibilities of pumped storage used in conjunction with normal hydro development, and with high load-factor nuclear supply, and, as always, he approached this matter with wisdom as well as enthusiasm.

Mr. Lawrie's outstanding success in promoting hydro-electric development was due not only to his wide knowledge and experience but to the excellent judgment which he brought to bear on the many difficult problems inherent in hydro-electric projects. He combined prudence and wisdom with great vision and foresight and worked untiringly for the success of the developments made possible by the Act of 1943. His mental qualities, combined with his training and experience, made him particularly fitted for managerial responsibilities, and his approach to problems was a happy combination of human, economic and technological considerations. Those who had the privilege of working with him are especially aware how much Scotland owes to him and how great is the loss incurred by his early death.

He was made a C.B.E. in the 1953 Coronation Honours List. His friendly and courteous personality, keen sense of humour and quickness of mind made him a delightful person to work with, and his readiness to give guidance and help endeared him to a very wide circle of friends, by whom he will be most sorely missed. He leaves a widow, two sons and three daughters.

He joined The Institution as a Student in 1926 and was elected an Associate Member in 1928 and a Member in 1937. He was also a Member of The Institution of Mechanical Engineers, and a Fellow of the Royal Society of Edinburgh. T. G. N. H.

MONOGRAPHS AND PAPERS
published separately this month

Separate monographs and reprints of all papers published in the Proceedings are available at the price of 1s. 3d. each (post free). The inclusive charge for a copy of a paper allocated for reading at a meeting on separate publication and for a reprint of the paper and discussion (as republished in the Proceedings) is 2s. 6d. (post free). This charge is made whether or not the reprint is required, but a reprint alone costs 1s. 3d. as noted above. However, separate copies of a paper allocated for reading are supplied free of charge 10 days before the first meeting at which the paper is to be read, whether in London or in the provinces. If a reprint also is required, a remittance should accompany the request. Reprints of a paper being read at a meeting cannot be issued before the paper and discussion have appeared in the Proceedings, but they should preferably be ordered before or shortly after the paper has been read in London.

In an order, a monograph or a paper can be specified completely by the author's surname and the serial number of the paper. Those who wish to avoid making a separate payment for each monograph, paper, or reprint which they require can obtain books of voucher-labels, price 10s. each, containing 8 vouchers, on application to the Secretary.

A list of papers published in the November issue of Part B of the Proceedings appears under "Contents of the Current Issues of the Proceedings" on page 726, and the serial number of each paper and the month of publication of a digest in the Journal are included. Synopses of both monographs and papers which will be published separately before the next issue of the Journal appear below, and unless otherwise stated, their date of publication is the same as this issue of the Journal. The monographs will be republished in Part C of the Proceedings, and the relevant Part for the republication of a paper is given after the serial number of the paper.

MONOGRAPHS

Peak Voltage Measurements of Standard Impulse Voltage Waves

MONOGRAPH No. 153 M

A. AKED, B.Sc.

The frequency spectrum of a 1/50 microsec impulse wave is obtained by the use of the Fourier transform. The corresponding frequency spectrum of the output from a simple capacitance potential divider, suitable for use up to 300 kV, is calculated from the input frequency spectrum for a 1/50 microsec wave and the frequency response of the divider, measured up to about 3 Mc/s. From this output frequency spectrum, the output at a time of 1 microsec is calculated, and thus the divider ratio, suitable for peak-voltage measurements, is estimated. Consideration is given to errors due to the limited frequency range of the measurements, and the accuracy of the measurement of the divider ratio is estimated to be better than $\pm 1\%$.

A digest of the monograph will be published in Part A of the *Proceedings*.

An Introduction to the Analysis of Non-Linear Control Systems with Random Inputs

MONOGRAPH No. 154 M

J. F. BARRETT and J. F. COALES, O.B.E., M.A.

By way of introduction, the Wiener method of optimization of linear control systems with noisy inputs is briefly set out, attention being called to the reasons why this method cannot be used directly for systems containing non-linear components. It is then shown that the difficulty with random inputs arises because the probability distribution of the output can be calculated only when the probability distribution of the error signal is known, but in order to obtain the probability distribution of the error signal the distribution of input and output must be combined. Thus it is not, in general, possible to obtain explicit expressions for either the error function or the output. If all the distributions were Gaussian then spectral densities could be used to obtain a solution of the problem and this is the basis of Burt's method (not previously published) which is given in detail. Unfortunately, when the input of a non-linear component is Gaussian the output will be non-Gaussian, but in some cases it is possible to make the necessary approximation.

Finally, the possible use of topological methods to determine the stability of non-linear systems with random inputs is discussed.

A digest of the monograph will be published in Part A of the *Proceedings*.

Some Terminology and Notation in Information Theory

MONOGRAPH No. 155 R

I. J. GOOD, M.A., Ph.D.

The main purpose of this paper is to stimulate thought concerning terminology, notation and exposition of some basic parts of information theory. The notation used here is intended to be simple and nearly self-explanatory. Moreover, sufficient generality is preserved so that entropy and conditional entropy can be interpreted without *necessarily* depending on the "frequentist" definition of probability (as a limiting frequency in an infinite sequence of trials). Mention is made of some connections of the theory with inverse probability and with mathematical statistics in general.

A digest of the monograph will be published in Part B of the *Proceedings*.

PAPERS

The Instrumentation of a 14-inch Experimental Rolling Mill

PAPER No. 1933 M; PART B

S. S. CARLISLE, M.Sc., and G. W. ALDERTON, B.Sc.

The paper will be published on November 26th.

The paper describes the comprehensive instrumentation scheme recently developed and applied on the new 14 in experimental rolling mill in the British Iron and Steel Research Association (B.I.S.R.A.) laboratories at Sheffield. Roll force on each side of the mill, front and back tensions and strip gauge, by using the B.I.S.R.A. gaugemeter principle, are continuously indicated on high-speed servo-operated potentiometric indicators fitted with large pointers and dials. The supply voltage to all measuring elements and transducers in the system is at a frequency of 400 c/s, and a rational system of electronic units has been worked out which enables identical amplifiers to be used for all channels. Some of these

amplifiers are already in quantity production for other purposes.

In the a.c. gaugemeter system used the normal gauge-setting control is situated on the main control desk, and a device is included for automatically setting the zero of the gauge deviation indicator. Also the mill-screw setting data are fed into the gaugemeter system by Magslip transmission from the screw top. The five indicating dials are mounted in one unit on the mill housing. The whole instrumentation scheme is designed and laid out as a model system for industrial mills of this class.

Facilities are provided for experiments with various systems of automatic gauge control. A simple system of on/off control of the existing a.c. screw motors according to the gauge deviation has been successfully operated with a tolerance of only $\pm 0{\cdot}0005$ in.

Automatic tension control based on measured tensions may be used as an alternative to the present method of control of coiler-motor current with correction for radius of build-up.

The accuracy of the various measuring systems is discussed in the light of experience gained so far, and attention is drawn to possible sources of error, particularly in the gaugemeter system.

A New Meter for the Kilovolt-Ampere-Demand Charge

PAPER No. 1927 M; PART A

P. BAXTER

The paper states that the introduction of an electricity tariff based in part upon a maximum apparent-power demand (VA m.d.) creates the need for a meter to measure apparent energy in a manner fair and just to all concerned. It gives two definitions for 3-phase apparent power and selects one as the more suitable basis for assessment of a maximum-demand charge.

A brief description is given of a Merz demand mechanism, which registers maximum demand (m.d.) from integrations made over definite time intervals. Reference is made to the difficulties of integrating 3-phase apparent energy (VAh) and these difficulties are held to be primarily responsible for the introduction of alternative methods of m.d. charging. Some of the alternative methods are briefly compared with that of the maximum apparent-power-demand charge, generally known as the kVA charge, in order to explain why so many attempts have been made to produce a true 3-phase apparent-energy meter. The paper recognizes that some very ingenious meters have already been designed but suggests that none is entirely satisfactory for industrial applications. It shows how recent developments have made possible the introduction of a new type of apparent-energy meter based on an entirely new principle.

A description is given of a new type of apparent-power indicating instrument, and this provides an introduction to a treatise on the new apparent-energy meter, whose main components are a dry-plate rectifier, a transductor and an induction-type integrating meter.

Remote Position Control and Indication by Digital Means

PAPER No. 1897 M; PART B

W. S. ELLIOTT, M.A., R. C. ROBBINS, B.A., and D. S. EVANS

In some applications, e.g. in accurate radar equipment, it is desirable to convert the angular setting of a shaft very accurately to digital form. A master binary disc is made photographically on a dividing engine. A photographic copy of the disc is coupled direct to the shaft whose setting is to be measured, and is scanned to produce a digital signal representing the shaft angle or a function thereof.

A number of convertors were made with scales subdivided to give an accuracy of about 1′. They were used under conditions of severe vibration and exposure, and amply demonstrated the principle of the high-accuracy binary disc. A follow-up servo was made and demonstrated, in which one shaft followed another by a digital link, to an accuracy of 1′. The limitation of accuracy is in the production of the binary discs. The master pattern can be subdivided and the photographic emulsion has ample resolution, but further work has to be done on the avoidance of small blemishes in the photographic processes.

The Manchester University Mark II Digital-Computing Machine

PAPER No. 1926 M; PART B

T. KILBURN, D.Sc., Ph.D., M.A., D. B. G. EDWARDS, Ph.D., M.Sc., and G. E. THOMAS, Ph.D., M.Sc.

The paper describes the Mark II digital-computing machine now operating in the Computing Machine Laboratory of Manchester University. It has a 100 kc/s parallel cathode-ray-tube store and a 1 Mc/s serial control, B-tube and accumulator. Thus the speed of the machine is inherently greater than that of its predecessor by a factor of ten. Orders which concern the B-tube or control are extracted from the store and obeyed in 60 microsec.

The machine has a floating-point accumulator, numbers being represented in the form $x2^y$, where x and y are respectively 30 and 10 digits in length. Numbers to be added to the accumulator are automatically shifted appropriately before addition; they are then added and the sum is standardized. An order involving such a floating-point addition is extracted from the store and obeyed in 180 microsec. Similar remarks apply to subtraction. For multiplication, which involves floating-point addition to, or subtraction from, the accumulator, the corresponding time is 360 microsec.

The number of thermionic cathodes in the Mark II machine is 57% less than that in the Mark I machine.

A comparison is made between the Mark II machine and a possible fixed-point version of it, so that the true importance of the floating-point accumulator can be ascertained.

Frequency-Modulation Radar for Use in the Mercantile Marine

PAPER No. 1940 R; PART B

D. N. KEEP, B.Sc.

The principles of f.m. radar are outlined and a comparison made between pulse and f.m. techniques, particularly with respect to the requirements of the merchant service. It is concluded that multi-gate f.m. radars are too complex for this application and methods are outlined for overcoming the inherently low scanning rate of single sweeping-gate systems. Equipment is described which has an aerial beamwidth of $1{\cdot}7°$ and a rotation rate of 10 r.p.m. with a fractional range resolution of 1/30.

The future of f.m. radar for mercantile marine use is critically examined and it is concluded that it will be most useful where very-short-range high-resolution pictures are required. Before such equipment is economically available further developments in transmitting valves must take place.

SOME RECENT BOOKS

E. A. BINNEY
ELECTRIC TRACTION ENGINEERING

CLEAVER-HUME PRESS. 224 PP. 15s.

This book is addressed to the new entrant to the electric traction industry: his prospects are now brighter than they have ever been.

Its core is an excellent introduction to the problems of the designer of equipment for electric and Diesel-electric rolling-stock. Not the least of its many virtues is a clear and largely non-mathematical description of the difficulties of commutation, particularly of the a.c. series motor. This is preceded by a brief description of the available systems of electrification and of the organization of the electric traction department of a large manufacturer and followed by a chapter on project engineering from his point of view.

One could wish the author had made a wider appeal by even a brief mention of such matters as power distribution, conversion and control, overhead equipment, operation and maintenance and their economics. All these subjects are comprised by electric traction engineering and offer more scope for useful and interesting careers than the young engineer may suppose. The author's appeal seems to be mainly to those about to engage in the design and manufacture of electrical equipment for rolling-stock. He succeeds in this limited field, although he does not stress that fundamental problems such as the mechanism of adhesion between wheel and rail, and of current collection, still await final solutions. The total possibilities for the young traction engineer are far wider and more exciting than he suggests.

The last paragraph of the book includes the surprising statement that "with the rising cost of labour and materials the justification of electrification becomes increasingly difficult." Paradoxically the reverse is true. These rising costs reflect scarcities and an increasing demand for higher standards of life. Electrification saves labour and materials and improves living and working conditions. As we stand to-day at the threshold of the peaceful use of nuclear power and of the economic use of current at commercial frequency for railway electrification, it actually becomes increasingly possible and urgent to electrify those many railways which still serve a useful purpose.

E. MOLLOY and W. E. PANNETT
RADIO AND TELEVISION ENGINEERS' REFERENCE BOOK

NEWNES. 1600 PP. £3 10s.

In recent years a number of scientific and technical reference books have been published; the editors and their contributors are to be congratulated on the one reviewed here. The whole concept of reference books has tended to change in recent years; before their increasing bulk and weight made the description inappropriate, they were often called "pocket books" and frequently associated with those fields such as chemical and civil engineering, which are dependent on constant reference to a large number of empirical formulae and physical constants that no one can hope to memorize. The new concept is towards a form of "canned library" which attempts to gather within one volume a complete professional engineering field such as that covered by the Radio Section of The Institution. If used with this conception in mind and with a comprehension of the limitations imposed, such reference books can be very valuable, but they should never be regarded as a painless substitute for wider and more fundamental knowledge.

The book is divided into 45 different sections, each written by an individual author and relatively self-contained, and usually followed by a bibliography. The contributors include many well-known radio and television engineers, and, with one or two exceptions mentioned later, the editors have succeeded in reaching a reasonable compromise between duplication of information and too much cross-reference.

The first three sections, on formulae and calculations, on optics and electron optics, and on materials, are the traditional "reference book" treatment of basic fundamentals in mathematics, physics and chemistry, and are very well presented; Section 45 on units and symbols, the last in the book, might well be grouped with them, since its content is surely inseparable from formulae. The remaining 41 sections divide naturally into three basic groups of Systems and Apparatus; Components and Component Techniques; and Servicing and Maintenance Techniques and Apparatus.

The first group ranges from Section 4 on studios and studio equipment through transmitters, transmission lines, waveguides, radio and television receivers, aerials and radar to Section 22 on communication receivers. In many sections there is evidence of the difficulties arising from the speed of development of the whole field and such subjects as frequency modulation and colour television are referred to only briefly, lending emphasis to the importance of new and *thoroughly* revised editions of this book being published regularly.

The second group covers subjects ranging from valves through transistors, resistors, electrical interference, recording and batteries to sound reproduction and distribution. The section on valves is comprehensive and includes newer devices such as travelling-wave tubes, but that on cathode-ray tubes is in places rather behind the times, e.g. it is astonishing to find a statement like "Metal-coned tubes are now made as the result of manufacturing difficulties with large glass tubes of about 16 in diameter or more," in a book published in 1955. Scanning techniques using ferrite materials, now an almost universal technique, should also find much greater prominence in this section, while the discussion over electromagnetic and permanent-magnet focusing is rather a matter of history in view of the trend towards electrostatic focusing, a technique which is hardly mentioned. Amalgamation of Section 26 on transistors and Section 27 on crystal diodes would have been useful since both contain introductions to semi-conductors, a subject also referred to under materials in Section 3. It is curious how no electrical reference book seems to be complete without a nostalgic reference to the Leclanché cell; surely the earlier part of the excellent section on batteries and conversion equipment could have been much shorter.

The third group on Servicing and Maintenance starts with measuring instruments and test equipments, then deals with transmitter and receiver installation and servicing, and ends with a section on measurement of noise factor, which is a model précis of a complex subject. Servicing and maintenance

are essentially difficult to learn from books, but the treatment provides a very good introduction and reference source in spite of some duplication of the section on instruments.

As a final summing up, this reference book is excellent value for money and well worthy of a place in the library of every radio engineer. It deserves full support in order to provide regular publication with up-to-date revisions.

A. G. E. ROBIETTE

ELECTRIC MELTING AND SMELTING PRACTICE

GRIFFIN. 354 PP. £2 10s.

The author's first book, published in 1935, was restricted to melting practice. There are many points of similarity between melting and smelting, and the decision to cover both operations in this new volume is logical. In each field problems arise which are not encountered in other branches of electrical engineering. The whole subject is highly specialized and justice can be done to it only by one who, like the author, has wide experience of its metallurgical and electrical facets.

The first three chapters of the book review contemporary practice in the arc-furnace melting of steel, iron, and non-ferrous metals, respectively. Referring to developments in steel-melting furnaces, Mr. Robiette emphasizes the trend towards increasing power input per unit of furnace capacity. Similarly, there has been an upward trend in operation voltage, and, whereas in the past a potential of 350 volts was rarely exceeded, the maximum voltage to-day may be 400 volts or more. Experience gained during the last war proved the superiority of air-blast circuit-breakers for arc-furnace work. Despite their higher installation cost these breakers score over oil breakers in requiring much less maintenance. Reference is made to recent developments in arc-furnace design whereby the melt is stirred electromagnetically through the agency of coils fixed to the underside of the furnace shell and fed with 2-phase low-frequency power. The stirring action is claimed to have useful metallurgical advantages.

The popular types of low-frequency induction furnace are fully described. The electrical characteristics of these core-and-loop units are discussed with particular reference to the question of power factor correction. The respective advantages of homopolar and heteropolar inductor-alternators for the supply of power to coreless induction furnaces are compared, and in favour of the latter it is pointed out that their lower field time-constant permits the strength of excitation to be more rapidly changed, a useful feature when rapid load-reduction is demanded as it simplifies high-speed capacitor-switching. Full operational details of the latest metallurgical practice in high-frequency melting are given.

The chapter on resistance melting discusses the use of metallic resistors for temperatures up to about 1 300° C and of graphite for higher temperatures. During the last twenty years the graphite-rod rocking resistor-furnace has been developed as an improvement on the old granular-carbon furnace. The larger sizes have 2-phase operation from 3-phase mains via Scott-connected step-down transformers.

Under the heading of smelting the author deals with iron, ferro-alloys and non-ferrous metals. Details are given of furnaces rated up to 24 000 kVA. Recent developments in the electric smelting of titaniferous iron ores are discussed.

Much can be said in favour of this book; it is complete in detail and affords the reader authoritative information on all important aspects of electric melting and smelting. Throughout a sensible balance between metallurgy and electrical engineering is preserved, and it should thus appeal to members of both professions. Engineers, students and others interested in this subject will find the book invaluable.

LAURA E. SALT and **ROBERT SINCLAIR** (*General Editors*)

OXFORD JUNIOR ENCYCLOPAEDIA
VOL. 8: ENGINEERING

GEOFFREY CUMBERLEGE. 512 PP. 30s.

Every engineer must have had the experience of answering the questions of children and laymen on the principles underlying his work. Whilst struggling to draw simple clear diagrams or to produce appropriate illustrations to accompany his explanations, he must have wished a *comprehensive* volume could be taken from his shelves to provide the information required. The volume under review goes far to meet this need; it does in fact fill a gap at the introductory level, which in the reviewer's opinion, has not hitherto had serious attention by publishers.

It is one of twelve volumes devoted to the more factual aspects of human knowledge. The other titles are "Mankind," "Natural History," "The Universe," "Communications," "Great Lives," "Farming and Fisheries," "Industry and Commerce," "Recreations," "Law and Order," "The Home" and "The Arts." The principal subjects in each volume are arranged alphabetically, and cross references are freely used, both within the volume and to other ones.

The foremost aim of the series was to provide a basic book of reference for school libraries which would also be found valuable by adults seeking simple enlightenment on unfamiliar topics. In reviewing a volume from this series one may assess its adequacy on familiar subjects and its clarity on unfamiliar ones: one may also "try it on the dog." From these three tests this volume emerges with high marks.

Inevitably there is some variation of style and treatment. Simple concepts are simply handled, but adjoining articles on more complex subjects sometimes appear to take for granted a wider knowledge than the other articles would provide. Some of the line drawings, especially those of turbines, fail to carry conviction, but most of them are excellent. Again, some photographic illustrations of machinery would not be understood easily by the uninformed, but there are many good half-tone illustrations and eight fine colour plates.

The text is usually remarkably up-to-date; e.g. the treatments of pre-stressed concrete construction, hydro-electric works and the automobile disc brake. Mistakes are negligible, but there are occasional curious omissions, such as the Unified Threads from a fairly full description of screw threads—but if this particular omission is due to prejudice, one may perhaps think the offence venial!

The book is well printed on art paper and bound in the familiar Oxford blue cloth. It is excellent value and may be confidently recommended for its intended purpose.

J. G. TRUXAL

AUTOMATIC FEEDBACK CONTROL
SYSTEM SYNTHESIS

MCGRAW-HILL. 688 PP. £4 9s. 6D.

This book aims to provide an advanced and complete treatment of servo-mechanism- and feedback-system design for post-graduate study and to act as a reference for research workers. It achieves its objectives with considerable success.

A familiarity with the basic principles of servo-mechanism theory is a necessary prerequisite to a study of this book and some practical experience would also be an advantage. As is

necessary in a volume of this nature the approach is largely mathematical, but the mathematics is essentially the engineer's variety. The physical interpretation is closely associated with the analysis and the purely mathematical aspects are given in footnotes and references.

As is appropriate to a post-graduate book the chapters are largely self-contained and the later chapters can be treated as independent theses on aspects of servo-mechanism synthesis.

Chapter 1 serves as an introduction and a review of the mathematical background, while Chapter 2 presents the signal-flow diagram as an alternative to the block schematic. The author claims significant advantages for the signal-flow diagram, but in the remainder of the book he uses the more familiar block schematic almost exclusively.

The material given on the synthesis of *RC* circuits in Chapter 3 is adequate for the purposes of the book and well provided with additional references. Chapter 4, headed "Root Locus Methods," presents an analysis of the way in which the poles and zeros of the complex-plane representation of the closed-loop system may be derived from those of the open-loop system, and traces by graphical means the dependence of these poles and zeros on the system gain. The interpretation of a specification of performance in terms of root-locus concepts is dealt with in the succeeding chapter.

The next chapter deals thoroughly with the more familiar Laplace-transform concept and its relation to the decibel/log-frequency approach. Methods of determining practical approximate approaches to idealized specifications are given, and a little is added to the end of the chapter on a.c. systems.

Two chapters follow on the principles and practice of statistical design. The concepts of the correlation functions and the power-density spectrum are established, and these are used to synthesize systems to the minimum-mean-square-error criterion. Chapter 9 deals adequately with sampling servo systems and the two final chapters are devoted to the describing-function technique and the phase-plane representation of non-linear servo systems.

The subject matter for a book of this nature is well chosen and presented. It is as readable as the material permits, and the principles are satisfactorily illustrated by a reasonable number of practical examples. The bibliography is almost wholly American in origin, and it is given only in a series of footnotes throughout the text.

H. S. TSIEN
ENGINEERING CYBERNETICS

McGRAW-HILL. 301 PP. £2 6S. 6D.

This is the most comprehensive book that has yet been published on the theory of control engineering. It is probably also the best exposition yet of the theory of linear control systems. The early chapters dealing with linear systems exhibit a remarkable clarity of thought which makes them easy reading. Mr. Tsien's examples are mostly aeronautical, ranging through gas turbines, guided missiles and high-speed aircraft, as might be expected from his work at the Guggenheim Jet Propulsion Centre, Pasadena. The fact that this field may be unfamiliar to many control engineers should not be a disadvantage, since it offers excellent examples to illustrate the theory and demonstrate how it may be applied in practice. Some of his examples lead to rather complex mathematical expressions and are difficult to follow for that reason, particularly for those not directly concerned with gas turbines or aircraft flight, but the problems are well worth working through as exercises in the practical application of the theory.

Having dealt with simple linear theory in the first four chapters, Mr. Tsien gives an excellent exposition of the general theory of the control of systems containing many variables, i.e. systems with a number of different parallel inputs and also a number of outputs that are not independent. This is a most important subject and one not previously treated in any published work; its study should result in advances being made in the analysis of multi-loop systems such as occur in chemical plants and in many other applications of automatic control in industry. Mr. Tsien's examples from gas turbine development demonstrate the method quite successfully, but its application to chemical plants is likely to be gradual because their characteristics are obscure.

His treatment of a.c. systems and simple servo mechanisms is brief and elegant, but almost entirely theoretical; that of linear systems with time-lag, including the important method derived by M. Satche,* is most valuable, but it is a pity the author could not use some simpler example to demonstrate it. Chapter 9, on linear systems with random inputs, contains methods of calculating the power spectrum of various types of input which should prove useful to the control engineer, and Chapter 16 is also a useful one, since it deals with the filtering of noise which is becoming very important in control system design. No examples are given of the use of these methods, which is perhaps unfortunate, since it is in the application that the chief difficulties lie. Chapter 10, dealing with relay servo mechanisms, is excellent from the theoretical standpoint, and so is the treatment of non-linear systems and of linear systems with variable coefficients. This is such a wide field that it is clearly impossible to do full justice to it in a book of this size; it is indeed remarkable how much of the most important work has been given in a very small space. Chapter 13 deals with control design by perturbation theory, at present almost unknown to control engineers but likely to prove of more importance now that the non-linear character of control systems is being taken into account. In this chapter the author makes the point, in dealing with the equations of motion of a rocket, that since the normal flight path is a good representation of the average situation, the deviations from the normal conditions are likely to be small, which is a principle that can be applied to most control systems and which is the justification for the use of the perturbation theory—a very effective method of analysis of a non-linear system. Chapter 14 deals with the design of systems with specified criteria, and Chapter 15 with methods of optimizing control systems which are, so far as the reviewer knows, quite novel. The object of optimizing is to change the parameters of a system automatically to take account of varying conditions of operation such as ambient temperature, wear of components or characteristics of the manufactured article differing from the intended design—very important considerations, which are, as a rule, ignored.

Finally, the author projects himself well into the future in two chapters inspired by Ashby's book,† "Design for a Brain," in which he considers systems having randomly varying components. Little thought has been given to the use of such methods in the design of man-made control systems, but they are known to exist in the biological world.

"Engineering Cybernetics" as a whole is a most remarkable work, excellently documented by references to the most up-to-date material. The book should lead the way to better understanding of control systems, and for this reason should be read by all students of control engineering.

* SATCHE, M.: *Journal of Applied Mechanics* (*ASME*), **16**, 1949, pp. 419–420.
† ASHBY, W. R.: "Design for a Brain" (John Wiley, New York, 1952).

ANNOUNCEMENTS TO MEMBERS

THE HOMES FUND

SUMMARY OF CONTRIBUTIONS RECEIVED TO 25TH OCTOBER, 1955

	No. of Contributors	£	s.	d.
£1 000 and over	6	6000	0	0
£100 to <£1 000	29	6386	3	0
£5 to <£100	770	8375	14	5
£2 to <£5	1829	5044	16	8
Under £2	17656	9382	14	4
		£35189	8	5

REGULATIONS FOR THE ELECTRICAL EQUIPMENT OF SHIPS

The Council have authorized the preparation of a Fourth Edition of the Regulations for the Electrical Equipment of Ships, to supersede the existing Third Edition (1939) as amended by the 1947 Supplement.

The work of preparation will shortly be undertaken by the Committee on Regulations for the Electrical Equipment of Ships, who will welcome the submission of comments or suggestions from interested bodies, and members or other persons. These should be addressed to the Secretary, and should reach him by the 1st January, 1956.

A CHRISTMAS LECTURE FOR SCHOOLCHILDREN

At the invitation of the Council, Mr. R. Brooks, B.Sc., Member, will deliver a Christmas Lecture on "Electric Traction." The lecture, which is intended for older schoolchildren, will be given in the Lecture Theatre of The Institution on the 29th December, 1955, at 3 p.m., and will be repeated at the same time the following afternoon.

Schools in the Home Counties are being invited to apply for tickets, and a number of tickets will be reserved for members' children, for which application should be made by December 1st, stating for which afternoon they are required. As accommodation is limited, members are asked not to accompany their children. The following is a synopsis of the lecture:

It will outline the principal features and methods of operation of the different systems of electric traction now in use, particular reference being made to the equipment of the locomotives and motor-coaches used on main-line and suburban services. The development of the modern traction motor will be traced from the basic work of Faraday through some interesting forms of early "electromagnetic engines."

The extent and distribution of electric traction throughout the world will be illustrated by a special map.

The present-day established systems of straight-electric operation (i.e. where the locomotive or motor-coach collects its power supply from an outside source) will be described with demonstrations, and some recent developments will be outlined. This part of the lecture will include an "arm-chair trip" in the driver's cab of a modern electric locomotive, with operation of the controls.

As an example of self-contained electric traction, the principles of the Diesel-electric locomotive will be described.

Finally, the lecturer will give a short talk on the main principles of electric railway signalling, together with a demonstration of full-size apparatus including searchlight-type signals.

The lecture will be illustrated with lantern slides and working demonstrations of some items of electric railway apparatus.

SCIENCE ABSTRACTS

An increase in the subscription rates for *Science Abstracts* to the general public has become necessary through increases in the cost of paper and printing. The Council regret that it will be necessary, therefore, to increase the specially reduced annual rates for members, which, as from the 1st January, 1956, will be £1 15s. (previously £1) for Part A (*Physics Abstracts*) £1 5s. (previously £1) for Part B (*Electrical Engineering Abstracts*) and £2 15s. (previously £1 15s.) for both Parts together.

BRITISH NUCLEAR ENERGY CONFERENCE

The first two of the regular monthly meetings of the Conference, on the 14th December, 1955, and the 18th January, 1956, will be sponsored by The Institution of Mechanical Engineers. The December meeting will be a General Meeting of that Institution in conjunction with the British Nuclear Energy Conference and will of course be open to all members of the constituent bodies of the Conference. It will be held in the Great Hall of The Institution of Civil Engineers, Great George Street, S.W.1, at 5.30 p.m., with tea at 5 p.m. No tickets of admission are required, but all those at the meeting are asked to sign the attendance register. Particulars of the paper, by Dr. J. M. Kay and Mr. F. J. Hutchinson, to be read on December 14th are given below, and advance copies of it will be available from the Secretary, The Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1; applications for these should include a stamped addressed label or envelope.

Synopsis:

The Pressurized Water Reactor as a Source of Heat for Steam Power Plants

By J. M. KAY, M.A., PH.D., and F. J. HUTCHINSON, M.ENG.

The authors, who are with Messrs. Kennedy and Donkin, discuss the possible application to steam power stations of nuclear reactors using either light or heavy water both as the moderator and coolant.

In the first section of the paper the problem of heat transfer from the fuel elements to the coolant is analysed. Some of the special difficulties with this type of reactor are discussed, in particular the problems of the pressure-vessel design and the difficulties associated with corrosive action of the water in the coolant circuit. The limitations set by heat flow and thermal stresses in the fuel elements are also examined.

In the second section some different arrangements for the external steam plant are compared. The problems of using a supply of saturated steam for the turbines are discussed. The authors examine the use of a separately fired superheater both technically and economically. Steam conditions and cycle efficiencies are compared in the different arrangements.

In the final section of the paper the authors consider the direct boiling-water reactor. Some of the problems associated with steam formation inside the reactor are mentioned and the possible range of steam pressures examined. Overall cycle efficiencies are estimated for the boiling-water reactor with and without the use of a separate superheater.

CHRISTOPHER COLUMBUS INTERNATIONAL PRIZE

AWARD TO SIR GORDON RADLEY

The Council have conveyed their warm congratulations to Sir Gordon Radley, who, jointly with Dr. Mervin J. Kelly, President of the Bell Telephone Laboratories, has recently been awarded the international Christopher Columbus Communications Prize for work on the transatlantic telephone project.

The terms of award governing this prize are:

The prize shall be bestowed every year to whomsoever has contributed in a remarkable way, by some initiative, discovery or research, during the preceding four years, to the progress of communications among men, be it in the technical or scientific fields or socially, to achieve the shortening of distances and co-operation among peoples.

For the purpose of making a selection for the bestowal of the prize, communications have been divided in the following four sections: Maritime, Air, Land and Telecommunication. The prize shall be conferred, in each year, to only one of the said four sections.

PROFESSIONAL CONDUCT

The Council give notice that they would not regard it as a breach of Bye-law 42 dealing with professional conduct and in particular of sub-clause (iii) (*e*) of that Bye-law, if a firm of consulting engineers which includes in its partnership those who are members of The Institution were to prepare a brochure containing a factual record of works completed or in hand, including a biographical note of the firm and its partners, so long as the brochure did not contain any offer of services and was supplied only to clients or potential clients who request such information.

The Council are confident that members acting as consulting engineers who issue brochures of the type described above will, in the words of Bye-law 42 (ii), "uphold the dignity of the profession of the Electrical Engineer."

THE 1956 SUMMER MEETING

The Council, on behalf of The Institution, have accepted with pleasure an invitation from the Chairman and Committee of the South Midland Centre to hold the Summer Meeting next year in the area of the Centre. The Meeting will take place from Monday evening, 25th June, to Friday evening, 29th June. This advance notice is given to enable those interested to reserve the dates. Further details will be announced in due course.

CONVENTION ON DIGITAL COMPUTER TECHNIQUES

9TH–13TH APRIL, 1956

A satisfactory number of papers has been offered for inclusion in the Convention. Authors who may have been unable to complete formal papers in time for advance publication are reminded that facilities are still available for them to present papers dealing with the most recent developments in computer techniques. Provided these papers satisfy the referees they may be read from manuscript at the Convention, and they will be considered for subsequent publication. Authors will, however, be required to provide synopses for printing in advance of the Convention. An author who desires to avail himself of this arrangement should, if possible, submit a brief synopsis at once and send the draft of his paper, in triplicate, not later than the 31st January, 1956.

CORRESPONDENCE

In view of the heavy volume of correspondence received daily at the offices of The Institution it is of the greatest assistance when members, in replying to letters received from the Secretary, quote The Institution's reference number. This saves the time of the routing staff and ensures that a letter not only reaches, without delay, the department concerned, but can be immediately linked with the previous correspondence. It is also helpful when members state their class of membership.

REGISTER OF MEMBERS—CHANGES OF ADDRESS

Members are reminded that notifications of changes of address should be made to the Secretary of The Institution in London. Where a transfer from the area of one Local Centre or Sub-Centre to another arises as a result of a change of address, this transfer is automatically arranged by headquarters and the member concerned need not notify also the Hon. Secretary of the Local Centre or Sub-Centre.

To obviate the possibility of errors in the records, members are particularly requested, when notifying a change of address, to give their full initials, their previous address and their class of membership.

SEMAINE DE DISCUSSIONS

We have been asked to announce the holding, by the Société Française des Electriciens from the 21st to 26th November inclusive, of a *Semaine de Discussions*, at their conference hall, 14 rue de Staël, Paris XV^{e}. The conference, in six Sections, will cover topics ranging from heavy electrical machines to telecommunication, and members of The Institution will be most welcome to attend.

PROFESSIONAL SANDWICH COURSES

The London and Home Counties Group of the British Association for Commercial and Industrial Education is holding a meeting on the 6th December, 1955, at 2.30 p.m. in the Reading Room of the Regent Street Polytechnic, London, at which Mr. H. E. Dance, of the Ministry of Education, will be talking on "Recent Developments in Professional Sandwich Courses."

The London Group of B.A.C.I.E. would welcome any members of The Institution at this meeting as visitors.

NAVAL ELECTRICAL OFFICERS' ANNUAL DINNER

The Annual Dinner of the Electrical Branch of the Royal Navy was held in H.M.S. *Collingwood* (Fareham), on the 30th September, 1955. Capt. K. R. Buckley, R.N., Commanding Officer of H.M.S. *Collingwood*, was President, and the Guest of Honour was Rear-Admiral Sir C. Philip Clarke, K.B.E., C.B.E., D.S.O., Member, who has recently retired from the Navy. The toast of the Electrical Branch was proposed by Capt. L. S. Bennett, B.Sc., R.N., and the toast of Rear-Admiral Clarke by Rear-Admiral K. H. T. Peard, C.B.E., Associate Member, the new Director of Naval Electrical Department. A record number—nearly 200—of regular and reserve officers attended the Dinner.

Next morning a small party of reserve officers toured the establishment, and to those who had not visited H.M.S. *Collingwood* for some years it was revealing to see the progress made in installing up-to-date naval electrical equipment and in improving training arrangements.

LIBRARY ACCESSIONS

**Denotes that the publication is also in the Lending Library. The publications cannot be bought through The Institution; the publishers and the prices are given only for the convenience of members.*

BOOKS

RZIHA, E. 621.31

Starkstromtechnik (Heavy-current engineering)

Vol. 1. 8th ed. Edited by R. Genthe. Berlin, Wilhelm Ernst, 1955. pp. xi, 1000. 21 × 15 cm. £6 4s. 3d.

SAY, M. G. 621.31

Electro-Technology *

2nd ed. (First published as "Electro-Technology and Calculations.") London, Newnes, 1955. pp. 167. 22 × 15 cm. 10s. 6d.

The first part of this book reviews briefly electrothermal, electrochemical, and magnetic field effects. Definitions are given and the rationalised M.K.S. system is used. The second part is a guide to circuit problems. It deals with two-terminal and four-terminal cases, and with balanced and unbalanced three-phase circuits. A collection of network theorems is included.

SEQUENZ, H. 621.313.045

Die Wicklungen Elektrischer Maschinen. Band III. Wechelstrom-Sonderwicklungen (The windings of electrical machines. Vol. 3. Special alternating-current windings)

Vienna, Springer-Verlag, 1954. pp. xix, 397. 25 × 18 cm. £6 4s. 6d.

SIEMENS BROS. & CO. LTD. 621.395.34

Traffic Calculations for Trunk and Local Telephone Exchanges *

London, 1955. pp. 103. 28 × 21 cm.

Gives the basic principles underlying the methods of calculating the equipment quantities for standard types of local and trunk exchanges except the No. 17 system.

STEPHENSON, R. 539

Introduction to Nuclear Engineering *

London, McGraw-Hill, 1954. pp. xii, 387. 24 × 16 cm. £2 17s. 6d.

Gives an introduction to the physics of the subject and an explanation of nuclear fission, the nuclear chain reactor and reactor theory. Then discusses the engineering problems involved in radiation shielding, the special requirements of materials used for constructional purposes, reactor instrumentation and control, chemical separations and processing, and techniques specially developed for handling, viewing, storing and transporting radioactive materials.

STEVENSON, W. D. 621.315.01

Elements of Power System Analysis

London, McGraw-Hill, 1955. pp. x, 370. 23 × 16 cm. £2 13s. 6d.

Discusses parameters of power lines, transmission line calculations in the steady state, fault calculations, and power-system stability—particularly under transient conditions. Contains worked examples and problems to be worked by the reader.

STORM, H. F. and others 621.318.42

Magnetic Amplifiers *

New York, Wiley; London, Chapman and Hall. 1955. pp. xix, 545. 24 × 16 cm. £5 8s.

Deals mainly with single-phase types. Discusses the modern theory of magnetism, characteristics of magnetic materials, magnetic testing, the theory and design of magnetic amplifiers, and applications.

TIRANTI, D., and WALKER, W. F. 658.5

Introduction to Production Control *

London, Chapman and Hall, 1946. pp. xix, 160. 22 × 15 cm. 15s.

Describes the way to organize a factory for production control, showing the information which must be gathered about the product to be manufactured, the machinery and labour available, the material required, and timing for scheduled working. It relates chiefly to batch production of engineering articles. There is a useful bibliography of books on the same and related subjects.

WAKEFIELD, E. H. (Editor) 539

Nuclear Reactors for Industry and Universities *

Pittsburgh, Instruments Publishing Co., 1954. pp. ix, 94. 21 × 13 cm. 16s.

Describes types of small reactor being developed which may be suitable, and economically possible, for universities and the larger private laboratories in the United States. Their operation and applications are discussed together with the precautions to be taken, and there is some mention of estimated costs.

WASS, C. A. A. 518.5

An Introduction to Electronic Analogue Computers *

London, Pergamon Press, 1955. pp. x, 237. 14 × 22 cm. £2.

Describes electronic computing elements for addition, sign-changing, integration, multiplication and division, resolution, etc., and procedures for solving a variety of problems. The d.c. amplifier and the automatic correction of drift are dealt with and there are chapters on time-scales, repetitive computers, and the setting up of computers and auxiliary apparatus. Some existing computers are described. The book will be reviewed in a future issue.

WIND, M., and RAPAPORT, H. (Editors) 621.317.029.6

Handbook of Microwave Measurements *

2 vols. New York, Polytechnic Institute of Brooklyn, 1954. Vol. 1, pp. 595. Vol. 2, pp. 341. 29 × 21 cm. $12.

A comprehensive review of the techniques which have been developed arranged in twenty sections, thus—attenuation, power, Q-factor, spectrum analysis, hybrid junctions, etc. The relevant diagrams and charts are assembled in a separate volume to be used side by side with the text. Bibliographical references are given and there is a subject index. This book will be reviewed in a future issue.

"WIRELESS WORLD" 654.19

Guide to Broadcasting Stations 1955–56

London, Iliffe, 1955. pp. 80. 18 × 12 cm. 2s. 6d.

Lists under wavelength and under geographical location details of broadcasting and television stations.

YOUNG, A. J. 621–52

An Introduction to Process Control System Design *

London, Longmans, Green, 1955. pp. xvii, 379. 22 × 14 cm. £2 2s.

This book is concerned not only with the design and characteristics of the controller but with the characteristics of the plant to be controlled. It points out the need for obtaining data about the actual performance of a plant as material on which the necessary mathematical analysis of it and the complete system can be based. The book will be reviewed in a future issue.

OTHER PUBLICATIONS

CONGRÈS INTERNATIONAL DE L'ALUMINIUM

Rapports Présentés au Congrès International de l'Aluminium. Paris, June, 1954

2 vols. Paris, Aluminium Français, 1954. pp. 358; 317. 28 × 22 cm.

CONSIGLIO NAZIONALE DELLE RICERCHE

Convegno di Elettronica e Televisione. Milan, April, 1954. Supplement to "La Ricerca Scientifica," Vol. 24, 1954.

2 vols. Rome, Consiglio Nazionale delle Ricerche, 1955. pp. 1202. 24 × 17 cm.

INSTITUTE OF RADIO ENGINEERS

1955 National Convention

10 vols. New York, Institute of Radio Engineers, 1955. 28 × 22 cm. $50.25.

INTERNATIONAL CONFERENCE ON LIGHTHOUSES AND OTHER AIDS TO NAVIGATION

Shore-Based Radio Aids to Navigation on Centimetric Wavelength, by J. M. F. A. van Dijk and others

Noordwijk, Netherlands Radar Research Establishment, 1955. pp. 11. 33 × 22 cm.

NETHERLANDS PHYSICAL SOCIETY

Proceedings of the International Conference on Semiconductors. Amsterdam 29th June to 3rd July, 1954

Amsterdam, Netherlands Physical Society, 1954. pp. viii, 337. 24 × 16 cm.

INTERNATIONAL COUNCIL OF SCIENTIFIC UNIONS

Mixed Commission on the Ionosphere. Proceedings of the Fourth Meeting held in Brussels, August, 1954

Brussels, Union Radio-Scientifique Internationale, 1955. pp. 238. 24 × 16 cm.

INTERNATIONAL SCIENTIFIC RADIO UNION

Proceedings of the XIth General Assembly held in The Hague 23rd August to 2nd September, 1954. Vol. 10, Part 4, Commission IV on Radio Noise of Terrestrial Origin

Brussels, Union Radio-Scientifique Internationale, 1954. pp. 60. 24 × 16 cm.

MINISTRY OF TRANSPORT AND CIVIL AVIATION

An Evaluation of the Decca Navigator System, by the Civil Aviation Navigational Services Group

London, Ministry of Transport and Civil Aviation, 1955. pp. x, 298. 33 × 20 cm.

Forthcoming Events at Savoy Place

All meetings are held at Savoy Place, beginning at 5.30 p.m. (tea at 5 p.m.), except where otherwise stated. The nature of the meeting is indicated by the following key:

E	EDUCATION DISCUSSION CIRCLE	**R**	RADIO AND TELECOMMUNICATION SECTION
I	INFORMAL	**S**	SUPPLY SECTION
M	MEASUREMENT AND CONTROL SECTION	**U**	UTILIZATION SECTION
O	ORDINARY		

After each paper that has now been published is added the month that its synopsis appeared in the *Journal*.

1955

NOVEMBER

21 *Monday* — E. P. WETHEY, B.SC., will open a discussion on "The Reception of Band I and Band III Television Programmes"† — **R**

23 *Wednesday* — J. S. MØLLERHØJ, M.SC., A. M. MORGAN, B.SC.(ENG.), *and* C. T. W. SUTTON, M.SC.(ENG.) — **S**
"Flat Pressure Cable" (Paper No. 1884 S)‖ *Synopsis:* July 1955

28 *Monday* — Section Soirée — **R**

29 *Tuesday* — C. J. N. CANDY, PH.D., B.SC.(ENG.) — **M and R**
"The Specification of the Properties of the Thermistor as a Circuit Element in Very-Low-Frequency Systems" (Paper No. 1751 M)‖ *Synopsis:* December 1954
"A Vector Method for Amplitude-Modulated Signals" (Paper No. 1772 M)‖ *Synopsis:* January 1955

DECEMBER

1 *Thursday* — LT.-CMDR. F. R. J. SPEARMAN, J. J. GAIT, M.A., B.SC., A. V. HEMINGWAY, B.SC.(ENG.), *and* R. W. HYNES, B.SC. — **O**
"Tridac—A Large Analogue Computing Machine" (Paper No. 1899 M)‖ *Synopsis:* October 1955

5 *Monday* — A. N. IRENS will open a discussion on "Private Generation from the Point of View of the User"* — **I**

* No advance information will be available.
† An abstract of the introduction will be available in advance.
§ This paper will be published not later than 10 days before the date of reading.
‖ This paper has now been published separately (see p. 715).

DECEMBER

6 *Tuesday* — S. S. CARLISLE, M.SC., *and* G. W. ALDERTON, B.SC. — **M and U**
"The Instrumentation of a 14-Inch Experimental Rolling Mill" (Paper No. 1933 M)§ *Synopsis:* See page 715.

7 *Wednesday* — R. S. WEBLEY, B.SC., H. G. LUBCZYNSKI, DR.ING., *and* J. A. LODGE, B.SC. — **R**
"Some Half-Tone Charge Storage Tubes" (Paper No. 1883 R) (published in the *Proceedings*, Part B, July 1955)

9 *Friday* — F. STEFANI, B.SC., will open a discussion on "Aids to Teaching the Subject of Windings in Rotating Machinery"* (At 6 p.m., tea at 5.30 p.m.) — **E**

12 *Monday* — ALVIN RAKOFF — **R**
Informal Lecture on "The Television Studio as seen by the Producer"‡

14 *Wednesday* — D. H. LUCAS, B.A., *and* M. E. PEPLOW, B.SC. — **S**
"The Measurement of Steam Temperatures in Power Stations" (Paper No. 1872 S)‖ *Synopsis:* June 1955

15 *Thursday* — A. NEMET, DR.ING., *and* W. F. COX, B.SC. — **U**
"Intensification of the X-Ray Image in Industrial Radiology" (Paper No. 1881)‖ *Synopsis:* July 1955

British Nuclear Energy Conference

NOVEMBER

30 *Wednesday* — INAUGURAL MEETING

At The Institution of Civil Engineers, Great George Street, S.W.1. It is regretted that no more tickets of admission can now be issued.

SYMPOSIUM OF LECTURES:

At 2.15 p.m.

SIR CHRISTOPHER HINTON, M.A., F.R.S.
Opening Address*

SIR JOHN D. COCKCROFT, K.C.B., C.B.E., M.A., M.SC.TECH., PH.D., F.R.S.
"The United Kingdom Atomic Energy Project"§

V. A. PASK, C.B.E., and J. A. DUCKWORTH, B.A.
"The Place of Nuclear Energy in United Kingdom Power Development"§

At 5.15 p.m.

H. J. GROUT, B.SC.
"The Use of Research Reactors in Nuclear Power Development"§

A. S. MCLEAN, M.B., CH.B., D.I.H., *and* W. H. MARLEY, M.SC., PH.D.
"Health and Safety in a Nuclear Power Industry"§

After each of the lectures by Mr. Pask and Mr. Duckworth, by Mr. Grout, and by Dr. McLean and Dr. Marley, there will be a discussion. There will be an interval for tea from 4.45 to 5.15 p.m.

DECEMBER

14 *Wednesday* — A meeting sponsored by The Institution of Mechanical Engineers to be held at The Institution of Civil Engineers, Great George Street, S.W.1. No tickets of admission are required.

J. M. KAY, M.A., PH.D., *and* F. J. HUTCHINSON, M.ENG.
"The Pressurized Water Reactor as a Source of Heat for Steam Power Plants"¶

* No advance information will be available.
† An abstract of the introduction will be available in advance.
‡ A synopsis will be available in advance.
§ For synopses see October *Journal*, pp. 665–6.
‖ This paper has now been published separately (see p. 715).
¶ For synopsis, see p. 720.

Elections and Transfers

The following elections and transfers approved by the Council are effective from the 22nd September, 1955.

ELECTIONS

Graduates

ALLON, Henry.
ANDREWS, Reginald Francis John.
ANYADIKE, Francis Ohashiegbula Onyema Egbulinye.
BARNES, Ronald.
BARRITT, Ernest Whitehead.
BEARD, Robert Charles, B.E.E.
BODEN, Peter Standidge.
BROOKS, Edward Lees.
BRYAN, Henry Gwilym, B.Sc.
BUNNING, Ronald Hanby.
BURDALL, Albert Arthur.
CLARE, Kenneth Walter.
CLARK, Frederick Samuel.
COCHRANE, William Ingram.
COX, Trevor John.
DEMPSEY, Henry.
DENNIS, Michael Wesley, B.A.
DUNCAN, Robert Wilson.
DUNK, Desmond Sydney.
EDMONDS, Peter Hicks.
FLACK, Arthur.

Graduates (contd.)

FOWLER, Lawrence Nicholas.
FRITH, Cyril Lewis.
GEMMELL, John Lewthwaite, B.Sc.
GILL, Kenneth, B.Sc.
GILLESPIE, William Reid.
GIORLA, David Peter Joseph.
GLASS, Reuben, B.A., B.Sc.
GLEDDEN, Derek.
GRANEAU, Peter, B.Sc.(Eng.).
GREEN, Gordon Leigh.
GREEN, John.
GUNSON, Cedric William.
HARRISON, William Siegfried, B.A.
HAYWARD, Peter Commander, B.E., B.Sc.
HODKINSON, Derek Windsor.
HOGG, George MacGregor, B.Sc.
HOLMES, Ronald.
HORRIGAN, Anthony Augustine.
HUNTER, Ronald.
IDASIAK, Bronislaw, B.Sc.(Eng.).
JESUDIAN, David Ratnaraj, M.A., B.Sc.
JONES, John Meirion.
JONES, Michael William.
JONES, Owen, B.Sc.
KIAYAS, Nicolas Georgiou.
KIMBER, Colin Spencer.
LANGMAID, John, B.A.
LAVERICK, John Edward Hall.
LEWINGTON, Peter John Charles, B.Sc.
LINES, Thomas Raymond.
LIVINGSTONE, Harold.
LONG, Ronald Edwin.
MACKERETH, Joseph Henry, B.E.
McLACHLAN, John McCallum.
MARSHALL, George Armstrong.

Graduates (contd.)

MATTHEWMAN, William.
MEIKLE, Francis Wood.
MELIE, Chike.
MIDFORTH, John Keith.
MONCUR, Henry Anderson.
MORRISON, John Gordon.
NEILSON, John Nairn.
NEVIN, Barry James.
NEWSAM, Bernard Unwin, B.Sc.
PADFIELD, Francis Clare, Flt.-Lt., R.A.F., B.Sc.
PEACOCK, Frederick William.
POMELLA, Piero Luigi Vittorio, B.Sc.
POOLE, John Michael, B.A.
POTTS, John Robert.
RACZKO, Henry.
RAINA, Kul Bhushan, B.A.
READ, Roy William.
RENDALL, Martin.
REY, Robert Arthur.
RICKINSON, Frederic.
RIGGS, Michael.
ROLLO, Peter Eric, B.E.
SCHWENK, Albert Frank Basil.
SEN, Jit.
SETH, Ram Kishore, M.Sc.
SHEPHERD, Philip Letchford, B.Sc.(Eng.).
SULEK, Michal.
SYKES, Leslie.
TAIT, John Burnett James, B.E.
TALMAGE, Anthony George.
TAN, Eddie Ghee Soon, B.E.
THOMAS, Neville Norman, B.A.
TRIM, Richard Morris.
VARLEY, Keith, B.Sc.
VASEY, Thomas Watson Cornforth.
WADDINGTON, Gordon.
WILSON, Herbert Edward.
WOODFIN, Thomas James, B.A.
WOOLDRIDGE, William Howard.
WORSTALL, Michael Vincent, B.A.

Students

ABBI, Yagya Pal, B.Sc.
AHLUWALIA, Surendra Singh, B.Sc.
ALLEN, Philip Geoffrey.
ALLOS, Janan Emmanuel.
ANDERSON, George Daniel.
ASHIQ, Ehsan Ahmed.
BELL, Robert William.
BHALLA, Ramesh Kumar.
CAWDERY, Anthony Devereux.
CHASE, Brian Collison.
CHERIAN, Varghese, B.Sc.(Eng.).
CRAPPER, David Hugh.
DAWSON, William Roger Courtlandt.
DILLISTONE, David Cecil.
DOWDALL, William Joseph.
DOWLER, Ronald Keith.
DOWNES, John Thomas.
EAVES, Charles Dennis.
FERNYHOUGH, Morris.
FLEMING, John Eric Edgcumbe.
GOLSBY, Robin James.
GREEN, Dennis.
HAQUE, Mohammad Inamul.
HERRETT, Russell James.
HOLDER, Brian.
KARRAS, George Solon.
KESH, Anil Kumar, B.E.E.
KHWAJA, Maqsud-ul-Ahsan.
KIPLING, Rudyard William.
KROL, Jerzy Romuald.
LAWLER, Fergus Philip.
LEE, Thomas Joe.
LEWIS, Keith.
LOFTING, Anthony Edward.
MACARIO, Raymond Charles Vincent, B.Sc.
MACKAY, Colin.
MALLINSON, Michael Peter Durell.
MUSTAFA, Nouzad Majid.
NADKARNI, Suresh Shankar, B.E.
NAGARKATTI, Durgesh Narayan, B.E.
NATH, Sunil Chandra, B.Sc.
NICHOLAS, George Delevan.
NIMMO, Dickson Alexander Wardlaw.
NIX, George Francis.
NIXON, John Frederick.
NOHRIA, Kewal Krishan.
PAGEDAR, Arvind Kamalakar, B.E.
PALMER, Brian Charles Malcolm, B.Sc.
PANANDIKAR, Vijay Satyashraya, B.E.
PANG, Patrick Ting Kin.
PAPWORTH, George Geoffrey Guy.
PARSONS, David John, B.Sc.(Eng.).
PENROSE, George Stanley.
PERKINS, Harold.
PHIPPS, Colin Ray.
PICHAI, Venugopal, B.Sc., B.E.
PICKWORTH, Cecil Henry John.
POPE, Terence.
PRIVETT, Ian Donald.
RAINFORD, Maurice Vernon.
RANADE, Suresh Parashuram, B.E.
SEHGAL, Rajinder Kumar.
SENIOR, Frank William.
SERIKI, Lateef Omotayo Adio.
SIZMUR, Malcolm Frank.
SOMERS, Desmond James.
SPENCER, Raymond John, B.E.
SRIVASTAVA, Gopal Saran.
STANLEY, Graham Edward.
TAIWO, Akinola Adebayo.
TREADGOLD, Jack Richard.
WATT, Brian Horace.
WHITE, Kenneth Edward.
WHITTAKER, Peter George.
WILCOCK, Arthur.
WILLIAMS, Brian John.
WOOTTON, Herbert John.
YOUMANS, David Michael, B.Sc.
YOUNAN, Harith.

TRANSFERS

Student to Graduate

AL-RIFAI, Rashid Mohamed Said, B.Sc.(Eng.).
AYLOTT, Gordon William, Instr.-Lt., R.N., B.Sc.(Eng.).
BAILEY, Arthur Raymond, B.Sc. (Eng.).
BALL, Michael.
BIRCH, Robert Eric, B.Sc.
BLAKE, John Sedgwick.
BRACKIN, Royston Anthony.
BRAUDE, Israel David, B.Sc., B.Sc.(Eng.).
BRIDGNELL, Ian Christopher.
CLARKE, Denis Richard, B.Sc.
COOK, James Enir.
COOK, Kenneth Alexander.
DAVIES, William Emlyn.
DEVEREUX, Daniel.
EAST, Donald.
FASS, Herman, B.Sc.(Eng.).
FIELDER, Peter Wyatt, B.Sc.(Eng.).
FOSTER, David.
FREEMAN, David Lillycrop, B.Sc. (Eng.).
FRENCH, John Rowland, B.Sc.
GEORGE, Edward Ambrose, B.A.
GOLDING, Michael Ernest, B.Sc.
GOODWIN, Richard John Chester.
HAIGH, Douglas Noel, B.Sc.(Eng.).
HALE, Rodney Barker.
HANLON, Keith George.
HARDY, Ernest Colin.
HARKER, Thomas, B.Sc.
HELLER, Jerzy Horacy, B.Sc.
HILBIG, Maxwell John, B.E.
HOLDEN, Alistair David Craig, B.Sc.
HOLMES, Peter Geoffrey.
IRESON, Robert Charles James.
JOHNSTONE, Raymond.
KNIGHT, John Harry.
KRISHNAMURTHY, Ramaswamy.
LAING, John Douglas, B.Sc.(Eng.).
LATHAM, Herbert, M.Sc.
LAWSON, Tony Eric.
LOWETH, Peter Augustus.
MARK, George Wilson, B.Sc.
MENSAH-BROWN, Joseph Paschal Kweku.
MITCHELL, Frank Ronald Goodwin, B.Sc.
MORRIS, Derek Ernest.
MUNDY, Robert James.
MURPHY, Brian Anthony, B.Sc.
NISBET, David Baird.
NORMAN, Ernest Archibald.
O'DEA, John Joseph, B.Sc.(Eng.).
O'NEILL, Terence Martin, B.E., B.Sc.
PALLES-CLARK, Peter Christopher.
PRICHARD, John Tuson, B.Eng.
RAWLINS, Robert Frank.
RICH, David Arthur, B.Sc.
ROBERTS, George Michael.
ROSCOE, Glyn Owen, B.Sc.
RYAN, William David, B.Sc.
SALMON, John William, B.Sc.(Eng.).
SHEARD, Fred.
SHOUBRIDGE, Gerald Raymond, B.Sc.(Eng.).
SMITH, Raymond Linton.
SWEET, John Charles.
THOMAS, David.
THOMPSON, Michael Hamilton.
THURBON, Michael Thomas.
TOMKINS, Alan Gordon, B.Sc.
WATT, Samuel Andrew.
WEBSTER, David Muckart.
WILKES, Gordon Ronald.

Student to Graduate (contd.)

The following elections and transfers approved by the Council are effective from the 1st October, 1955.

ELECTIONS

Associate Members

ALGATE, Leonard Joseph.
CAMBROOK, Clement Arthur, B.Sc.
GRAYSON, Harry, B.Sc.Tech.
GROVES, Kenneth.
HODGES, Arthur Beauchamp.
HOPPER, Albert St. Clair, B.Sc.(Eng.).
JOHNSTON, Norman Balfour.
KIRBY, Thomas Greenhalgh.
LAL, Chuni, B.Sc.(Eng.).
LOUDON, William.
LUNT, John Alfred, B.Sc.Tech.
MINNIS, Francis Hugh Campbell Morgan, M.Sc.
POYSER, Frederick Leslie, B.Sc.
SUCKLING, Maurice Patrick.
TYRER, George Hubert.

Associates

CAPE, Brian.
HAYWARD, Horace Albert.
MacKENZIE, William, M.B.E.
PANTON, James Harold Eric, Col.
PASKIN, Sydney Howard.

TRANSFERS

Associate Member to Member

ARNOT, Alfred Reginald Erwin, B.Sc.(Eng.).
CARSON, Herbert Arthur.
GILES, Percy Albert.
HARPER, William Eric, B.Sc.(Eng.), Ph.D.
HEATON-ARMSTRONG, Louis John, B.Sc.
LEWIS, Gerald Breton, Lt.-Cmdr.
PATTON, William Archibald Hamill, B.Sc.
PEARCE, Richard Randle Spencer.
TAYLOR, George Austin.
THORNTON, Alfred Marcus, B.Sc.

Associate to Associate Member

COX, William Jabez George.
SIONS, Morris Ernest, B.Sc.
WALLEY, James William.

Graduate to Associate Member

AP RHYS, Tomos Llewelyn, B.Sc.
AVELING, Alan John, Flt.-Lt., R.A.F.
BRIERLY, Lionel, B.Sc.
BUSBY, Colin Henry, B.A.Sc.
COOPER, George Gordon.
CORMACK, Alan, B.Sc.
COURT, James Harrison, B.Sc.(Eng.).
DENNIS, Oswald.
DIXON, Anthony Arthur, B.Sc.(Eng.).
DONALDSON, Kenneth James Stuart.
DORF, Tim Donald, B.Sc., B.E.
DURRANT, Hugh Patrick, B.Sc. (Eng.).
EDEN, Eric James.
ENTICKNAP, Edwin.
FEAVER, John Lionel.
FIELD, Thomas Edward, B.Sc.(Eng.).
FISHER, Jim, B.Eng.
FOSTER, Cecil James, B.Sc.Tech.
GEERCKE, Sydney Munro George.
GILBERT, Edward William Neville.
GIRLING, Leonard Roy.
HARRIS, Kenneth William.
HEYMANN, Franz Gustav, M.Sc. (Eng.).
JONES, Crwys, B.Sc.(Eng.).
KIBBLE, Robert, B.Eng.
LAW, Geoffrey Langford.
LEVELL, Derek Alfred, B.Sc.
LOGAN, Donald James.
LUTON, Henry, M.A.
MacKELLAR, Alexander Campbell.
MACLEAN, Douglas James Hargrave, B.Sc.
OATS, Paul Harvey.
OSTROV, Leo.
PEAGRAM, George Wainwright.
POWELL, Robert George Sefton, B.E., B.Sc.
POYSDEN, William Dudley, B.E.
ROBERTSON, John Keith, Lt.-Cmdr., R.N., B.A.
ROBSON, Eric Richard.
SPRINGATE, John James.
TROJANOWSKI, Marian Stanislaw, Dipl.Ing.
WATSON, David, B.E.
WHITE, Gerald James, B.Sc.
WILLIAMS, Clifford.
WRAGGE, Hector.

Student to Associate Member

SCOTT, Robert William.
WHITE, Geoffrey, B.Sc.(Eng.).

Contents of the Current Issues of the Proceedings

DATE OF JOURNAL DIGEST OR SPECIAL ARTICLE

PART A. POWER ENGINEERING (OCTOBER 1955)

See October *Journal* page 674.

PART B. RADIO AND ELECTRONIC ENGINEERING (NOVEMBER 1955)

F. J. M. LAVER, B.SC.
November 1955 **An Introduction to Some Technical Factors affecting Point-to-Point Radiocommunication Systems** (PAPER No. 1925 R)

H. H. ROSENBROCK, B.SC.(ENG.), PH.D.
November 1955 **An Approximate Method for obtaining Transient Response from Frequency Response** (PAPER No. 1907 M)

Written discussion on **Standard Waveguides and Couplings for Microwave Equipment**

W. L. STEPHENSON, B.SC.
November 1955 **Measurements of Junction-Transistor Noise in the Frequency Range 7–50 kc/s** (PAPER No. 1811 R, MARCH 1955)

J. M. WADDELL, M.A., S. E. MAYER, PH.D., AND S. KAYE, B.SC.
November 1955 **A Germanium Diffused-Junction Photo-Electric Cell** (PAPER No. 1860 R, APRIL 1955)

R. A. HILBOURNE, B.SC., AND D. D. JONES, M.SC.
November 1955 **Transistor Power Amplifiers** (PAPER No. 1861 R, APRIL 1955)

L. H. LIGHT, B.SC., AND PRUDENCE M. HOOKER, B.SC.
November 1955 **Transistor D.C. Convertors** (PAPER No. 1862 R, APRIL 1955)

J. A. THOMAS, B.SC., AND R. W. E. MCNICOL, M.SC.
Digest not yet published **Automatic Recording of the Direction of Arrival of Radio Waves reflected from the Ionosphere** (PAPER No. 1932 R)

Discussion on **An Attracted-Disc Absolute Voltmeter** before the North-Western Centre

Discussion on **Thermionic Valves of Improved Quality for Government and Industrial Purposes** before the South Midland Radio Group and the North-Eastern Radio and Measurements Group

W. T. BLACKBAND, M.SC.
Digest not yet published **The Choice of Impedance for Coaxial Radio-Frequency Cables** (PAPER No. 1891 R)

R. E. COX, B.SC.(ENG.)
Digest not yet published **Traffic Flow in an Exponential Delay System with Priority Categories** (PAPER No. 1916)

J. A. LANE, M.SC.
Digest not yet published **The Measurement of Power at a Wavelength of 3 cm by Thermistors and Bolometers** (PAPER No. 1918 R)

Written discussion on **The Launching of a Plane Surface Wave**

Discussion on **Standard Frequency Transmissions, The Standard Frequency Monitor at the National Physical Laboratory,** and **Standard Frequency Transmission Equipment at Rugby Radio Station** before the North-Eastern Radio and Measurements Group

Written discussion on **Some Aspects of the Design of V.H.F. Mobile Radio Systems**

G. W. G. COURT, B.SC.
Digest not yet published **Determination of the Reflection Coefficient of the Sea, for Radar-Coverage Calculation, by an Optical Analogy Method** (PAPER No. 1917 R)

C. J. HUGHES, B.SC.
November 1955 **Signalling Systems for Submarine Telegraph Circuits** (PAPER No. 1908 R)

PROFESSOR A. L. CULLEN, PH.D., AND J. C. PARR, B.SC.
Digest not yet published **A New Perturbation Method for Measuring Microwave Fields in Free Space** (PAPER No. 1921 R)

Discussion on **Image Intensification in Radiology** before an Extra Meeting of The Institution

Discussion on **Technical Colleges and Education for the Electrical Industry** before the North-Western Centre, the Southern Centre and the East Midland Centre

Digests of Institution Monographs:

ULRIK KRABBE, PH.D.
The Residual Time-Constant of Self-Saturating (Auto-Excited) Transductors (MONOGRAPH No. 140 M, JULY 1955)

E. G. C. BURT, B.SC., AND O. H. LANGE, DR.RER.NAT.
Function Generators based on Linear Interpolation with Applications to Analogue Computing (MONOGRAPH No. 137 M, JUNE 1955)

D. J. WOOTTON, B.SC., AND A. F. PEARCE, PH.D.
A Reflex Klystron Oscillator for the 8–9 mm Band (MONOGRAPH No. 143 R, AUGUST 1955)

PART C. MONOGRAPHS (SEPTEMBER 1955)

See September *Journal* page 620.